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GEOGRAPHY, GEOLOGY, AND MINERAL RESOURCES OF THE FORT HALL INDIAN RESERVATION IDAHO

BY

G. R. MANSFIELD

WITH A CHAPTER ON WATER RESOURCES

BY

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ABSTRACT OF REPORT.

Introduction.—The Fort Hall Indian Reservation, which was examined in 1913, includes about 800 square miles in Bingham, Bannock, and Power counties, Idaho, and has been partly included in the Idaho phosphate reserve. Its interesting history is briefly outlined.

Geography.—The reservation contains two mountainous regions with broad valleys and an intervening area of plains bordering Snake River. The maximum difference in elevation is about 4,500 feet, and the broader valleys range from about 4,400 to 5,800 feet in elevation. The drainage is all tributary to Snake River.

The topographic history covers at least parts of three physiographic cycles, which are described. The climate is semiarid, and the rainfall in the broader valleys, which is fairly well distributed throughout the year, is about 13 inches annually. Severe temperatures are exceptional. Favorable areas have somewhat more than three months of security from frost. The vegetation includes some valuable timber. Besides agricultural, grazing, timber, and water resources, there are extensive deposits of high-grade phosphate rock in the eastern part of the reservation and some fine placer gold along Snake River.

Geology.—The stratified rocks of the reservation include representatives of all the great systems, beginning with the Cambrian. Certain Mesozoic formations are more fully subdivided in this report than in previous reports.

Igneous rocks occur in some variety and great abundance. An occurrence of nepheline basalt is noted. There were at least four epochs of volcanic activity, extending from Pliocene into late Pleistocene.

The complex geologic structure is due to both folding and faulting. The folds of the eastern part of the reservation are important because of their relation to the phosphate deposits, which occupy synclines. Both reverse and normal faults are present, but the chief interest is in the reverse faults. A noteworthy fault named the Putnam overthrust is described. Aside from the records of unconformities, at least three epochs of deformation are noted and referred to the post-Cretaceous, the late Pliocene, and the end of the early Pleistocene.

The geologic history is sketched.

Geology of individual townships.—Some townships that are believed to contain phosphate are described in detail and are shown on a scale of 2 inches to 1 mile. Particular attention is given to geologic structure and to phosphate deposits, including estimates of acreage and tonnage.

Phosphate deposits.—It is estimated that the Fort Hall Indian Reservation contains 738,526,700 long tons of phosphate rock that averages 70 per cent tricalcium phosphate and that is considered available under the standard of the Geological Survey. For the western field as a whole, partial estimates available May 1, 1917, give approximately 5,464,082,000 long tons of high-grade phosphate rock.

The present demand for the western rock is small because of distance from markets and high cost of transportation. In 1915 the field supplied only 0.2 per cent of the production of the whole country. The Fort Hall deposits are less accessible from existing railroads than the phosphate beds near Georgetown and Montpelier.

The western phosphates are believed to be original sedimentary deposits formed through biochemical agencies.

Other mineral deposits.—Coal and metalliferous prospects on the reservation have yielded no production, but placer mining in the Fort Hall bottoms has brought small returns. Some ore that averages 22 per cent copper has been shipped from the Moonlight property, just south of the reservation. Extensive deposits of volcanic ash may prove a valuable resource.

Soils.—The soils are calcareous and differ to some extent in texture and composition. Qualitative tests show no water-soluble carbonates and slight traces, if any, of sulphates and chlorides.

Water resources.—The reservation lies entirely within the drainage basin of Snake River. The characteristics of the flow of that river and of its tributaries, Blackfoot River, Portneuf River, Bannock Creek, and Ross Fork, are fully described.

In the more mountainous portion of the reservation the ground water has not been developed. Numerous wells have been dug on the terrace near the agency, which are described. Large springs occur on the plains near Snake River, which are attributed to the collection of surface waters on the plains west of the river.

A system has been constructed for the irrigation of a large area near Fort Hall. Other areas are irrigated in the valley of Bannock Creek and along Blackfoot River. Sites for the development of water power exist along Blackfoot River, Ross Fork, and Bannock Creek. Lands along Snake River are included in an important reservoir site.

GEOGRAPHY, GEOLOGY, AND MINERAL RESOURCES OF THE FORT HALL INDIAN RESERVATION, IDAHO.

By George R. Mansfield.

INTRODUCTION.

The geologic examination of the Fort Hall Indian Reservation was undertaken by the United States Geological Survey at the request of the Office of Indian Affairs. A narrow strip of land along the east border of the reservation had been included in the phosphate withdrawals, and the principal object of the examination was the determination of the extent and character of the phosphate lands included in the reservation. Other mineral deposits were also noted. The work was assigned to the writer with instructions to proceed with an examination and mineral classification of the Fort Hall Indian Reservation. G. R. Mansfield, with J. W. Merritt and J. W. Clark as assistants, spent the four months July to October, 1913, in the prosecution of the work. In the middle of September, after the withdrawal of J. W. Merritt, the party was joined by C. A. Bonine and Wallace Lee, who rendered valuable assistance. The chief of the section of nonmetalliferous deposits, H. S. Gale, spent the last week in July with the party. He participated in the mapping and made valuable suggestions with regard to plans and methods of work. G. H. Girty, paleontologist, was with the party for three weeks in August and September and made a faunal and stratigraphic study of the Carboniferous and Triassic formations.

LOCATION OF THE AREA.

The Fort Hall Indian Reservation lies approximately between meridians 112° and 112° 45′ west longitude and between parallels 42° 30′ and 43° 15′ north latitude. It includes an area of approximately 800 square miles in 32 townships and partial townships in Bingham, Bannock, and Power counties, Idaho. The location of the reservation is shown in the index map (fig. 1).

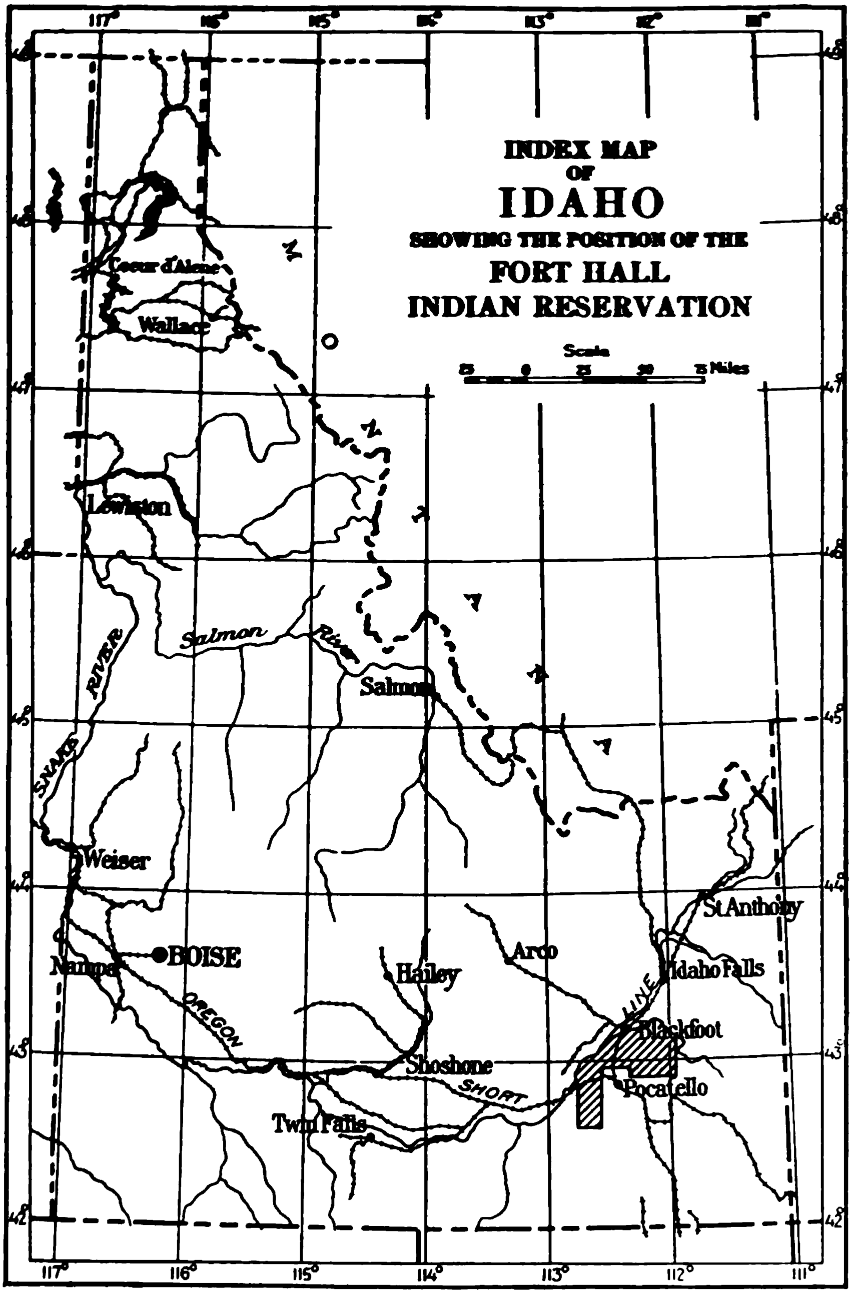

Figure 1.—Index map of Idaho showing the location of the Fort Hall Indian Reservation (shaded area).

The reservation lies on the northwest side of the Idaho phosphate reserve and includes a narrow strip of that district. The location

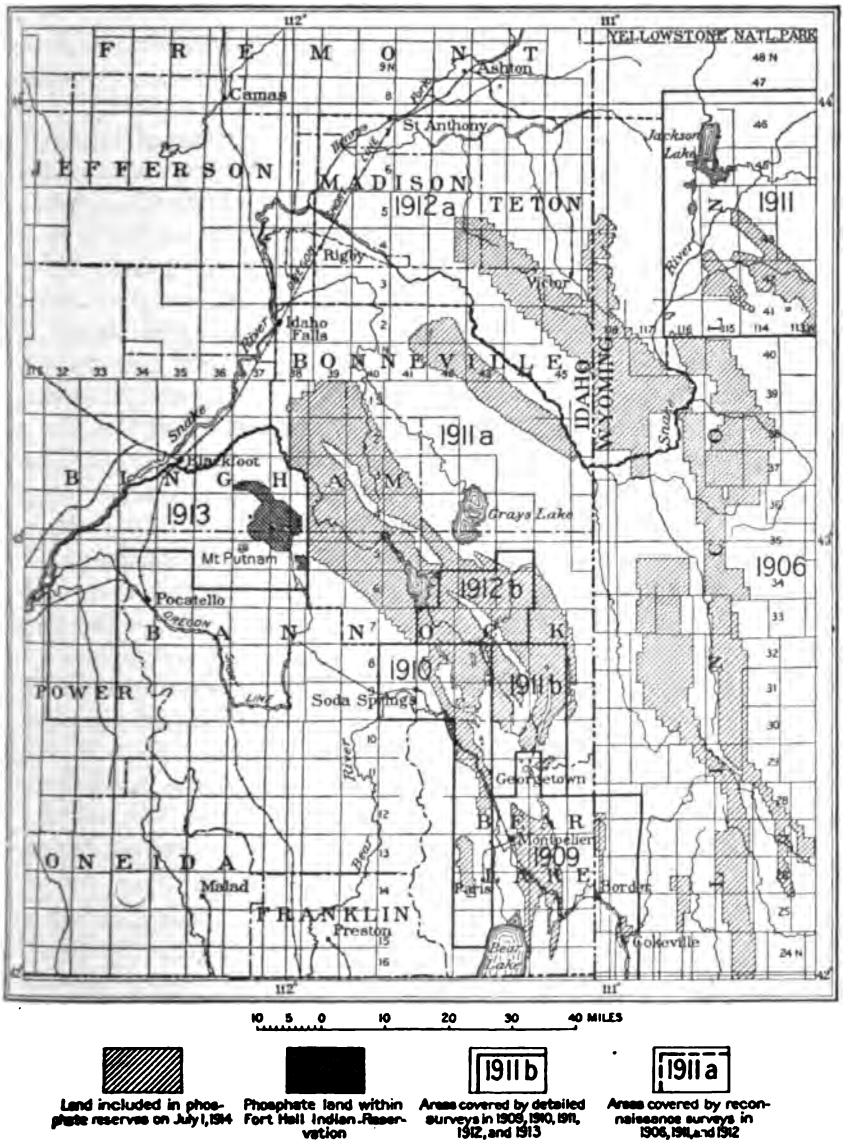

FIGURE 2.—Map showing the location of the Fort Hall Indian Reservation with respect to the phosphate reserve and the location of areas of the reserve examined in previous years.

of the reservation with respect to the phosphate reserve and to the areas examined in detail in previous years is shown on the accompanying map (fig. 2).

EARLY EXPLORATION AND HISTORY.

As far back as the later part of the eighteenth century this region was frequented by fur traders and trappers. The basins of Green, Bear, and Snake rivers abounded in valuable fur-bearing animals, and in the broad valleys the fur companies held their annual meetings for trade. Here also occurred many notable Indian conflicts.[1] An interesting picture of the country and of the activities of the trappers, traders, and Indians is given by Irving[2] in his account of the attempts of a party outfitted by John Jacob Astor to found a trading post at the mouth of Columbia River and also in his account of the adventures of Capt. Bonneville. The Astorians passed along Snake River on their way to the Columbia. Their party met with reverses at the hands of the Indians and endured many hardships.

Capt. Bonneville spent parts of two seasons in 1833 and 1834 in the area that is now included in the Fort Hall Reservation. At that time the region near the head of Portneuf and Blackfoot rivers was an extensive buffalo range. Capt. Bonneville spent a winter on Snake River near the Portneuf, where he noted the presence of fine springs of water. Some of these springs, he says, "gush out of the earth in sufficient quantity to turn a mill and furnish beautiful streams, clear as crystal and full of trout of large size."[3] The reference here, with little doubt, applies to Spring Creek and Clear Creek, with other lesser streams that rise on the plains of Snake River within the reservation. A chance associate of Capt. Bonneville was Nathaniel J. Wyeth, a trader of Boston, Mass., who in 1834 established a trading post on Portneuf River which he named Fort Hall. "Here for the first time the American flag was unfurled to the breeze that sweeps the great naked wastes of the central wilderness."[4]

The establishment and naming of Fort Hall is described by Wyeth in a letter, as follows:

> Since mine of June 21 from Hams Fork, I have, as I then proposed, built a fort on Snake or Lewis River, in latitude 43° 14′ N. and longitude 113° 30′ W., which I named Fort Hall, from the oldest gentleman in the concern. We manufactured a magnificent flag from some unbleached sheeting, a little red flannel, and a few blue patches, saluted it with damaged powder, and wetted it with villainous alcohol; and after all it makes, I do assure you, a very respectable appearance amid the dry and desolate regions of central America. Its bastions stand a terror to the skulking Indian and a beacon of safety to

[1] Gannett, Henry, U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, p. 708, 1879.

[2] Irving, Washington, Astoria, 2 vols., Philadelphia, 1836; The adventures of Capt. Bonneville, U. S. A., in the Rocky Mountains and the Far West, Pawnee ed., vols. 1, 2, New York and London, 1898. H. H. Bancroft (Works, vol. 28, pp. 568–575, 1884) scathingly denounces Bonneville and his expedition and censures Irving for presenting the captain and his works in so favorable a light.

[3] Irving, Washington, The adventures of Capt. Bonneville, U. S. A., in the Rocky Mountains and the Far West, Pawnee ed., vol. 1, pp. 324–325, 1898.

[4] Idem, vol. 2, p. 329. See also Bancroft, H. H., Works, vol. 28, pp. 585–587, 1884.

the fugitive hunter. It is manned by 12 men, and has constantly loaded in the bastions 100 guns and rifles. These bastions command both the inside and the outside of the fort. After building this fort I sent messengers to the neighboring nations to induce them to come to it to trade, and am now about starting with an equipment of goods for the winter trade.

In his journal, under date of August 6 of the same year, Wyeth writes:[5]

Having done as much as was requisite for the safety of the fort and drank a bale of liquor and named it Fort Hall in honor of the oldest partner of our concern, we left it and with it Mr. Evans in charge of 11 men and 14 horses and mules and 3 cows.

The site of Wyeth's fort is marked by a monument on the northwest bank of Spring Creek near the bridge in sec. 18, T. 5 S., R 33 E., as shown on the map (Pl. III).

Frémont,[6] in his exploring expedition of 1843–44, descended Bannock ("Pannock") Valley to the region of the lower Portneuf. Fort Hall had then become a British trading post under the Hudson Bay Co. Frémont noted the agricultural possibilities of the region and collected a sample of the soil, the analysis of which is given on page 118.

Capt. Stanisbury[7] made a similar trip down the Bannock Valley in 1849. The region was also included in later surveys for the purpose of locating wagon roads in the late fifties and early sixties.[8]

The United States Geological and Geographical Survey of the Territories, in charge of F. V. Hayden, in the late sixties and seventies mapped a strip of country in eastern Idaho. The reservation was not included in the Hayden maps, but the eastern part of it was visited by several geologists attached to these surveys, and some account of the district is given in their reports, to which more extended reference will presently be made.

The reservation was established by act of Congress on July 3, 1868, ratified February 16, 1869, and proclaimed February 24, 1869.[9] The reservation as then constituted included a considerably larger area than at present. Various modifications of its boundaries have since been made, reducing its area until its present limits were determinated by the act of June 6, 1902.[10]

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[5] The correspondence and journals of Capt. Nathaniel J. Wyeth, 1831–1836, edited by F. G. Young: Sources of Oregon history, vol. 1, pts. 3–6 incl., pp. 146–147, 227, Oregon Univ. Contrib. Dept. Economics and History, Eugene, Oreg., 1899.

[6] Frémont, J. C., Narrative of the exploring expedition to the Rocky Mountains in the year 1842 and to Oregon and north California in the years 1843–44, London, 1846.

[7] Gannett, Henry, op. cit., p. 709.

[8] Gannett, Henry, op. cit., p. 710. Bradley, F. H., U. S. Geol. Survey Terr. Ann. Rept. for 1872, 1873. (Cites Capt. Mullan, Wagon road Rept., 1863.)

[9] Treaty between the United States of America and the Eastern Band of Shoshones and the Bannock Tribe of Indians: Stat. L., vol. 15, p. 673, 1869.

[10] Stat. L., vol. 31, p. 672, 1901. Other acts relating to lands of the reservation may be found in Stat. L., vol. 22, p. 148, 1883; vol. 25, pp. 452, 686, 1889; vol. 26, p. 1011, 1891.

Shortly after the establishment of the reservation, about 1870, the military post of Fort Hall was built in the valley of Lincoln Creek in sec. 13, T. 3 S., R. 36 E., about 30 miles northeast of the old trading post on the Portneuf. Fort Hall served as an important supply point for some of the survey parties under F. V. Hayden, who speaks in glowing terms of the kindness and hospitality of the officers in charge there. About 1878 the agency was transferred to its present site on Ross Fork Creek and the Oregon Short Line Railroad. This railroad, under the name Utah & Northern, was completed as far north as Blackfoot in the fall of that year. The former site has been given over to agriculture.

From 1908 to 1911 various surveys have been conducted by the United States Reclamation Service and the United States Geological Survey at the request of the Office of Indian Affairs for the purpose of investigating the irrigation and power possibilities of the streams of the reservation. An account of the results of this work is given in the chapter on water resources by W. B. Heroy.

GEOGRAPHY.

PHYSIOGRAPHIC DEVELOPMENT.

SUBAERIAL EROSION.

The Fort Hall Indian Reservation occupies part of an extensive mountainous region that is underlain chiefly by layers of rock of unequal hardness and so bent and broken by earth movements that the edges of many of the layers have long been exposed to the action of snow and ice, wind, weather, streams, and gravity—the processes summarized in the words subaerial erosion.

The action of such erosion, though of varying intensity, is continuous and may in time be expected to wear away the hardest rock and level off the roughest country if the conditions under which it takes place remain unchanged. Two types of changes, however, are likely to interrupt the leveling process, namely, renewal of earth movements and climatic variation. The first, by raising, lowering, tilting, or warping certain parts of the region, alters the grades of streams and perhaps induces other changes that may have far-reaching effects. The second, by varying the amount of precipitation or the temperature, may change the volume and grade of streams or otherwise affect erosive action. Thus it seldom happens that an extensive region is completely leveled by subaerial erosion. Usually the process is interrupted and renewed under different conditions, which impose their own effects upon the surface or topography of the country as developed during the preceding erosional period.

Such changes may have occurred several times in a given territory. They serve to divide the time during which erosion has acted into periods of greater or less length, which are conveniently termed cycles or partial cycles, in accordance with the degree of perfection in surface leveling attained before the interrupting changes occurred. Each cycle is distinguished by the topographic features developed in it. The records of earlier cycles are modified and may be nearly or quite obliterated during succeeding cycles. In the Fort Hall Indian Reservation three partial cycles have been identified. These are named, respectively, the Putnam, Gibson, and Spring Creek cycles. The changes by which they were brought about are briefly considered in the sections on structure and historical geology.

PUTNAM CYCLE.

The mountains of the reservation are in general characterized by smooth, rounded slopes and summits. The slopes descend in long, sweeping curves, which become more and more gentle toward broad valleys or basins. The branch valleys in the higher parts of the mountains are also rather open, with fairly gentle side slopes. The broader valleys and basins as a rule have been developed where conditions were favorable, as along the strike of relatively weak rocks. The intervening harder rocks, which generally trend north or northwest, form strike ridges that furnish numerous side branches for the main valleys and are cut through here and there by deep transverse valleys. In T. 4 S., R. 37 E., the trends are prevailingly southwest to northeast.

The sloping surfaces developed on the harder rocks are steeper than those on the weak rocks, and along the mountain sides the region of change between the steeper and gentler slopes is fairly well marked and constitutes the upper boundary of the so-called benches, which are the gentler portions of the long slopes that descend to the valleys.

The slopes of the mountains and the adjoining benches have been carved from rocks that are inclined at different angles. This fact and the relations between ridges, valleys, and rock structure and character mentioned above indicate that the cycle of subaerial erosion, which shaped the features, was of long duration. It had reached a stage which may be called "late maturity," because the rougher outlines of surface produced by the streams in earlier stages of erosion had been largely subdued and the valleys, which at first were narrow and steep-sided, had been greatly broadened at the bottom and made widely flaring at the top.

The hard rocks, however, were not all worn smooth. Rough, rocky remnants of the former upland occur here and there on some

of the mountains and strike ridges, notably on North Putnam an South Putnam mountains, in the eastern part of the reservatior which are respectively 8,837 and 8,989 feet above sea level and ar 2,000 to 4,000 feet higher than the floors of the neighboring valley These are the highest mountains in the reservation and are als the highest peaks of the northern part of the Portneuf Rang Similarly, Bannock Peak, in the southwestern part of the reserva tion, has an altitude of 8,321 feet, and the local difference of eleva tion thereabouts is 1,000 to 2,000 feet.

The erosion cycle which produced this late mature topograph may be designated for future reference the Putnam cycle, fron Mount Putnam, in the vicinity of which it is well developed. Plat I, *A*, illustrates this topography as seen from the southwest flank of Mount Putnam. The canyons shown in this view were carved in the succeeding cycle. (See also Pl. I, *C*.)

GIBSON CYCLE.

Moister climatic conditions accompanied by elevation or warping of the surface ushered in the Gibson cycle. The topographic features of the Putnam cycle have been modified by the cutting of steep-sided canyons, 500 to 1,500 feet deep, in the older valley floors in regions of harder rock. In most of these canyons the new valley floors have been somewhat widened, and there is room for a wagon road or trail. The benches have been cut away at their lower borders in many places and now end in steep slopes, locally as much as 100 feet high. The surface of the bench lands is cut by branching canyons and gullies, the larger of which have well-developed flood plains, and is divided by them into somewhat irregular strips. The flood plains merge at their lower ends with a broad plain, 6 to 8 miles wide, that extends toward Snake River. This plain lies at the base of the steep slopes at the lower ends of the benches. It is really a terrace; for near Snake River it is cut away and the present flood plain of that river intervenes at a level about 75 feet lower, near the mouth of the Portneuf. The broad upper plain is here called the Gibson terrace, from the little settlement of Gibson, which stands upon it. The cycle in which the Gibson terrace and the associated features described above were developed may be called the Gibson cycle.

In any physiographic cycle the erosive processes work backward along the drainage lines so that the lower portions of valleys with their relatively broader streams may have extensive flood plains while the tiny headwater streams are still walled in narrow canyons and gorges. Thus the divides are the last features of a region to be reduced by subaerial erosion. Although in the Gibson cycle erosion

ROSS FORK CAN

e canyon around the
mbrian beds; *f*, Brig

had made considerable progress at lower elevations, as above outlined, it had not affected noticeably the higher parts of the mountains and the divides except at a few places. The Gibson cycle was therefore much shorter than the Putnam cycle. It may be said to have reached an early mature stage of development.

Plate I, *A*, illustrates a portion of the more rugged topographic features of the Putnam cycle together with some of the canyons and dissected benches of the Gibson cycle.

SPRING CREEK CYCLE.

A third cycle has been well started in the vicinity of Snake River by the development of the broad flood plain known as the Fort Hall bottoms. This plain extends up the lower courses of Portneuf and Blackfoot rivers and of Bannock Creek. The inclination of the plain is slightly greater than that of the Gibson terrace, so that the difference in elevation between the two, which is greatest near the mouth of the Portneuf, diminishes and finally disappears up each of these streams. In the bench lands some of the streams have cut 10 feet or more below the level of their former flood plains, but few if any topographic effects have been produced in the hard rocks of the hills. The present streams are apparently smaller than those which cut the canyons of the Gibson cycle. In fact, some of these canyons now have no drainage channels except in their middle or lower parts. A stream in the northeast part of T. 4 S., R. 36 E., affords an example of this condition.

This cycle has been much shorter than either the Putnam or the Gibson cycles. It may be said to have reached only a youthful stage of development. For reference it may be called the Spring Creek cycle, from Spring Creek, a relatively large stream that rises and has its entire course in the Fort Hall bottoms.

VOLCANIC FEATURES.

Flows of lava which have solidified and the products of volcanism have played an important part in the physiographic development of the region. Hills capped by such lava are striking topographic features in the Bannock Valley region and in Tps. 3 and 4 S., R. 36 E., and elsewhere. Large dikes which have been eroded form prominent hills, as in the northeastern part of T. 8 S., R. 32 E., and the adjoining part of T. 8 S., R. 33 E. Volcanic ejecta constitute a considerable part of the materials upon which the bench lands have been developed and lie upon the surface of the Gibson terrace and the low hills of solidified lava to the east. A youthful volcanic cone that is illustrated in Plate IV surmounts similar hills in the southwestern part of T. 3

S., R. 36 E. Erosion of hardened lava has formed the canyon of Blackfoot River, 300 feet or more deep, along the northeast border of the reservation and the flat-topped hills or mesas in the northern part of T. 9 S., R. 32 E. Caving of the hardened lava has produced depressions, as in sec. 34, T. 8 S., R. 33 E.

DRAINAGE RELATIONS.

The drainage of the reservation shows a considerable degree of conformity to rock structure. Numerous valleys and ridges follow the strike of the rocks, as shown in Plate II, A. Some valleys have also been excavated along fault lines. The strike ridge in the vicinity of the southeastern part of T. 3 S., R. 37 E., is cut by a number of small northeastward-trending faults that have been followed by stream valleys. These faults have divided the ridge in such a way that when viewed from the southwest it resembles a row of nearly conical hills. The conformity of stream valleys to structure was more pronounced in the Putnam cycle than in either of the later cycles. In the Gibson cycle there were marked tendencies toward such conformity. It seems probable that the upper waters of Wood Creek in the vicinity of the southwest corner of T. 3 S., R. 38 E., formerly flowed northwestward into Lincoln Creek but were diverted by capture to a northeasterly course into the Blackfoot during that cycle. The stream that formerly occupied the lower valley of Wood Creek was enabled by a shorter course and steeper grade to work back rapidly enough to tap the other stream and thus effect the capture.

The Fort Hall Indian Reservation includes an eastern and a southwestern mountainous region separated by the broad plains of the Gibson terrace and the Fort Hall bottoms. All streams in the reservation are tributary to the Snake-Columbia system, and the water ultimately finds its way to the Pacific Ocean. In each of the three broad divisions of the reservation, however, there are important streams that deserve mention.

The eastern mountainous region, which is roughly about 20 miles square, has four principal streams—Blackfoot and Portneuf rivers, which flow directly to the Snake; Lincoln Creek, a tributary of the Blackfoot; and Ross Fork Creek, a tributary of the Portneuf. The Blackfoot receives directly the drainage of the northern and northeastern borders of the district. Lincoln Creek drains much of the central and northern parts. The headwaters of the Portneuf occupy a broad basin in the eastern and southeastern regions. The Portneuf leaves the reservation in its southeast corner, and after a course of many miles to the south and west reenters it near the Gibson terrace, in the northeast corner of T. 6 S., R. 33 E. Ross Fork Creek has a

A. CHARACTERISTIC STRIKE RIDGE OF HIGHAM GRIT IN SEC. 18, T. 3 S., R. 38 E.

Note the comblike continuation of the ridge along the horizon. *a*, Nugget sandstone; *b*, Wood shale; *c*, Deadman limestone; *d*, Higham grit; *e*, Timothy sandstone; *f*, Portneuf limestone.

B. CEDAR TREE IN VIGOROUS CONDITION GROWING PROSTRATE BECAUSE OF EXPOSURE TO HIGH WINDS.

The tree is one of a group of similar trees on a high ridge in the NE. ¼ sec. 25, T. 9 S., R. 32 E.

large basin in the southwestern part of the eastern mountains and drains much of their central and western districts. It joins the Portneuf in the vicinity of the Gibson terrace, near the center of T. 5 S., R. 33 E.

The southwestern mountainous region forms a nearly rectangular area 20 miles long from south to north and 10 miles wide. The broad valley of Bannock Creek, which has a similar trend, divides the mountainous upland into two unequal parts, of which the western is more extensive but less rugged, except in the southern part. Rattlesnake Creek from the east and Moonshine and Starlight creeks from the west are the principal tributaries of Bannock Creek within the reservation. Michaud Creek, which is tributary to the Portneuf basin but is absorbed by the loose soil in the plains, drains most of the northeastern part of the district.

In the region of the Gibson terrace and the Fort Hall bottoms, Blackfoot and Snake rivers form, respectively, the northern and northwestern boundaries of the reservation. The Portneuf gathers most of the drainage except Bannock Creek, which flows west in T. 6 S., Rs. 33 and 32 E., and joins the Snake a short distance west of the reservation. In the lower part of its course the Portneuf is greatly increased in volume by receiving the waters of Spring Creek and Ross Fork with its large tributary Clear Creek. Numerous springs, large and small, supply the waters of Spring and Clear creeks, streams 60 to 100 feet or more wide, that originate and have their entire courses on the Fort Hall bottoms.

CLIMATE.

By W. B. Heroy.

The Fort Hall Indian Reservation lies on the eastern border of the Snake River plains but reaches eastward and southward into the mountain and valley region of southeastern Idaho. Though in general the climate of the region is semiarid, this diversity in topography is reflected in local climatic variations, the upland and mountain areas having a lower mean annual temperature and a greater rainfall than the plains.

The only climatologic station on the reservation is at Fort Hall. It was established in 1914, and the record is too short to be of much value. The records obtained by the Weather Bureau at a number of stations near the reservation afford, however, an indication of the climatic influences which prevail in this region. The stations at American Falls (1890 to present), Idaho Falls (1880 to present), and Pocatello (1899 to present) have been maintained for 18 years or more, a period of sufficient length to reveal cyclic tendencies. Stations at Blackfoot, Blackfoot dam, Chesterfield, Pebble, and Spring-

field were established more recently but serve to reveal local variations in climate, resulting from topographic and other influences. The normal monthly and annual precipitation at certain of these stations is given in the following table:

Average monthly and annual precipitation, in inches, at stations near the Fort Hall Indian Reservation, Idaho.

Station.	Elevation.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	Feet.													
American Falls....	4,341	1.66	1.22	1.58	1.27	1.63	1.09	0.65	0.50	0.76	1.15	1.33	1.30	14.14
Blackfoot..........	....	1.05	.76	.93	.86	1.60	1.03	.81	.65	.78	1.11	.88	.86	11.32
Chesterfield........	5,454	1.50	.97	1.36	1.00	1.85	1.44	.64	1.07	.85	1.09	.88	1.15	13.76
Idaho Falls........	....	1.62	1.12	1.56	1.08	1.70	1.54	.67	.76	.96	1.20	1.00	1.15	14.36
Pocatello..........	4,483	.66	.85	1.75	2.02	2.20	.99	.63	.56	.88	.98	.55	.86	12.93

In order to show the recent climatic history of the region the records above listed have been used as a basis for a diagram (fig. 3) which shows the variation in the annual rainfall for the years 1891

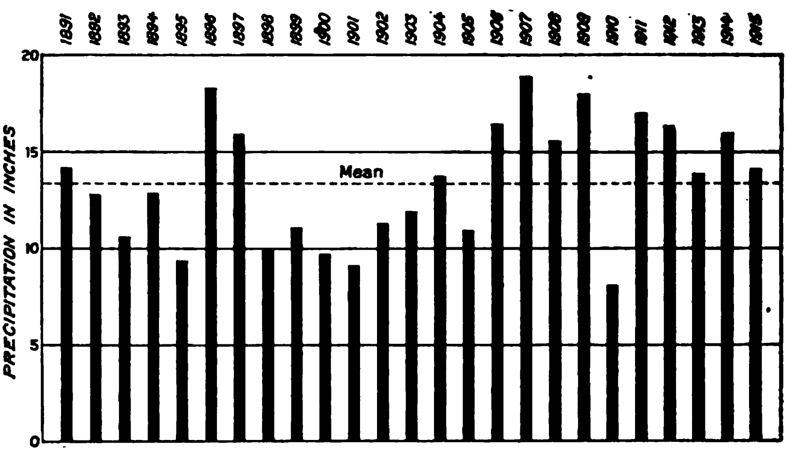

FIGURE 3.—Diagram showing variation in annual precipitation in vicinity of Fort Hall Indian Reservation during the years 1891 to 1915.

to 1915, inclusive. The rainfall given for each year is the average for the stations listed. The American Falls, Idaho Falls, and Pocatello records were used for the period 1891 to 1897. The Blackfoot record was substituted for the American Falls record for the period 1908 to 1915, as the latter record is incomplete. The other stations were used to fill gaps in the longer records.

The lowest average annual precipitation shown on the diagram is 7.94 inches, which occurred in 1910, and the highest is 18.78 inches, which occurred in 1907. The smallest annual precipitation recorded in this region was observed at Aberdeen in 1910, and was only 0.35 inch. The largest precipitation was 27.35 inches, which was observed at Pebble in 1911.

The mean annual rainfall for the entire period 1891 to 1915 is 13.38 inches. The most severe dry period recorded is that which includes the six years 1898 to 1903, the average for those years having been only about 10.5 inches. The period of greatest precipitation occurred in 1906 to 1909, the mean for these four years being 17.15 inches. The mean annual range of temperature in this region is from approximately —20° F. to +70° F.; January is the coldest and July the hottest month. The extreme range of temperature, however, is much greater, being about 130°. Certain relations of temperature are brought out in the diagram (fig. 4), on which are indicated the curve of the maximum, minimum, and mean monthly

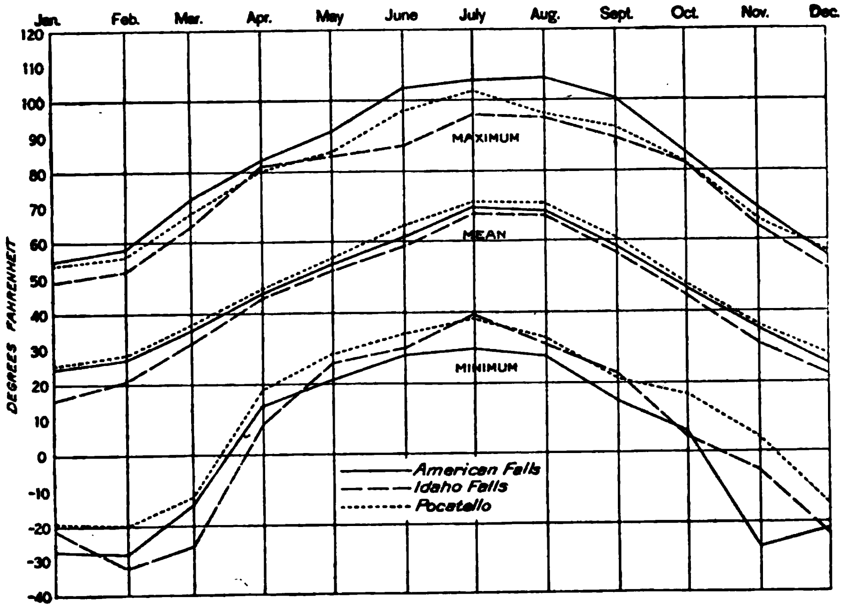

FIGURE 4.—Diagram showing relation between maximum, mean, and minimum monthly temperature at American Falls, Idaho Falls, and Pocatello, Idaho.

temperatures at the three principal stations—American Falls, Idaho Falls, and Pocatello.

As shown by a nine years' record the average date of the last killing frost in the spring at Pocatello is April 20 and that of the first killing frost in the autumn is October 12. The length of the growing season is thus about 175 days. At American Falls, as shown by a fifteen years' record, the corresponding dates are May 27 and September 8, and the length of the growing season thus indicated is 103 days. At Idaho Falls a four years' record indicates that the growing season averages 112 days in length, from May 22 to September 12. The much greater length of the growing season at Pocatello than at American Falls and Blackfoot may perhaps be due to th

direction of the prevailing winds. At Idaho Falls the prevailing winds are from the northeast throughout the year and sweep down the Snake River valley. In contrast the winds at Pocatello are prevailingly from the southeast and come down the Portneuf Valley.

The season of security from killing frost in the more favorably located parts of the reservation is probably somewhat more than three months. Frosts, however, may occur during any of the summer months along some of the valley bottoms, though they are not frequent in July and August. The bottom lands are therefore not adapted to any but the hardiest crops. On the sides of the valleys, on slightly higher ground, the cold air does not linger, and the ground is adapted for cultivation.

VEGETATION AND ANIMAL LIFE.

Sage and other low brush occupy much of the lowlands, lower bench lands, and low hills of igneous rock in relatively dense growth, although there are more or less extensive areas of open grass land, as in the northern and central parts of T. 5 S., R. 36 E., the northern part of T. 7 S., R. 32 E., and elsewhere. The upper benches and the windward slopes are also largely open and covered with grass. Grassy meadows occupy most of the larger stream valleys.

The lower rocky hills and ridges are largely forested with cedar, but in areas where the older dolomites come to the surface there is a considerable growth of mountain mahogany (*Cercocarpus ledifolius*), as in the southeastern part of T. 5 S., R. 36 E., and the northeastern part of T. 6 S., R. 36 E. In fact, in these localities the mahogany was found to be a convenient guide to outcrops of the dolomite.

Aspen thickets, some of them almost impenetrable, occupy the lee slopes of many of the larger ravines both in the bench lands and in the hills. They are also abundant on the lee slopes of hills. The drifting snow, which has to a large extent determined the location of these thickets, has weighted their branches and overloaded their tops so that many of the trees are stunted, gnarled, and twisted and their branches are closely interlaced.

The higher and more rugged districts in the vicinity of the North and South Putnam mountains and of Bannock Peak support, in addition to large groves of aspen, excellent timber, including Douglas fir, lodgepole pine, and balsam. These districts also have extensive thickets of brush and are littered with much fallen timber, though there are also open grassy places.

Large game is scarce in the reservation. Two antelopes and the tracks of a bear were seen by members of the party. Probably, too, there are a few deer and elks, but none were seen. Coyotes are numer-

ous. Small game is relatively abundant. There are rabbits by the thousand, together with some badgers, porcupines, and other smaller animals. Game birds, including members of the grouse and duck families, are abundant, and there are many other kinds of birds. There are many insects of different kinds, but no attention was given to genera and species. The flying ants proved a veritable pest. Fish are present in most of the larger streams but not in great numbers.

ADAPTATIONS OF LIFE TO ENVIRONMENT.

The grouping of the different types of vegetation has already been pointed out. This grouping is, without doubt, a response to environmental conditions in which the relative supply of moisture is probably the controlling factor, as is illustrated by the location of aspen thickets in the places where snowdrifts linger. In other places the type of soil may play an important part, as in the location of the mountain-mahogany groves and perhaps in the distribution of sage and the so-called oak brush in the lava hills in T. 4 S., R. 36 E. Where the dark volcanic sand is thick the sage gives way to the oak brush. This fact served as a guide in the study of the distribution of the volcanic sand.

The effect of the wind on vegetation on exposed slopes is noteworthy at a number of localities, particularly on a ridge in the NE. ¼ sec. 25, T. 9 S., R. 32 E., where stunted cedars, in vigorous growth, lay completely prostrate, pointing away from the prevailing wind, and some of them resembling couches of boughs. (See Pl. II, *B*.)

In the northern part of T. 4 S., R. 34 E., dunes have been formed of volcanic sand mingled with the finer sand of the Gibson terrace. A number of these dunes have been utilized by the Indians as the sites of burial places. These burial sites are marked by many high poles and by implements and personal effects of the deceased Indians.

An interesting item of organic response to environmental conditions was noted in the southwestern part of T. 7 S., R. 32 E., where the surface was underlain by weathered rhyolite. Ants, in search of uniform material for their mounds, had selected the quartz crystals weathered from the rhyolite and were thus living in veritable crystal palaces, which gleamed and glittered in the sunlight.

INDUSTRIES.

Outside of the reservation, as in Bannock Valley and elsewhere, the broad valleys are farmed from hillside to hillside. The plains are also devoted to raising potatoes, grain, and sugar beets. Within the reservation agriculture is being attempted by many of the

Indians under the guidance of district farmers, appointed by the Government. The agricultural developments, though promising, are not extensive and apparently as yet only partially successful. Much of the available agricultural land had not been subjected to cultivation at the time of the writer's examination. A considerable number of cattle and horses are pastured on the reservation, but the available pasturage was then only partially used.

NATURAL RESOURCES.

The timber of the higher districts furnishes fuel and building material. This resource is being utilized to some extent by the Indians.

The small game affords a supply of food in the open season, of which advantage is taken by the Indians. As others are prohibited from hunting on the reservation, this supply remains plentiful.

In addition to the agricultural, grazing, timber, and game resources, there are valuable deposits of phosphate rock in the eastern part of the reservation. These and other mineral deposits will be discussed more fully in a later part of this report.

Water is available for power and irrigation in parts of the reservation. Surveys and investigations in connection with this resource have been made under the authority of the Office of Indian Affairs. These are discussed in a later chapter by Mr. Heroy.

TRANSPORTATION.

The Oregon Short Line Railroad traverses the reservation north of the Bannock Valley district and west of the eastern mountainous district. Fort Hall has the only passenger and freight station within the reservation, but sidings are maintained at Michaud and at Gibson. Blackfoot and Pocatello are important railroad points just outside the reservation.

Much of the higher country is relatively remote from the railroad, but there are numerous roads in all except the most rugged districts. Stage and mail connections from the south are maintained at Chesterfield, about 3 miles southeast of the southeast corner of the reservation, and at Arbon, about 8 miles southeast of T. 9 S., R. 32 E.

POWER.

Power transmission lines cross the reservation in two localities. One line extends across the southwestern part of the reservation parallel to the railroad and carries energy from the water-power plant of the Southern Idaho Water Power Co., at American Falls, eastward to Pocatello. From Pocatello a line extends north to Blackfoot, also parallel to the railroad. This line supplies the agency ildings with light and power for the water-supply system.

GEOLOGY.

PREVIOUS GEOLOGIC WORK.

The observations of Bonneville and Frémont have already been noted (p. 12). The reports of the Hayden Survey have hitherto been practically the only source of information regarding the geology of the area now included in the Fort Hall Indian Reservation, and these refer only to the eastern part of the reservation.

In 1871 Hayden [11] traversed parts of this region on his way from Ogden to Fort Hall, in Lincoln Creek, and again from Fort Hall to Evanston, Wyo. He gives a brief account of his itinerary on each trip.

In 1872 F. H. Bradley,[12] in charge of one of the Hayden parties, traversed a portion of the eastern part of this reservation. In his report he gives an account of a stratigraphic section, the fossils from which as described by Meek have become well known through comparison with the Spergen fauna of the central States.

In 1877 A. C. Peale, in charge of one of the Hayden parties, crossed the southeastern part of the present reservation. In his report on the geology of the Green River district he discusses the drainage and geologic relations of the Portneuf Valley, Marsh Creek, and the Portneuf Range. He describes the structure of the Portneuf Range, of which Mount Putnam is the culminating point, as monoclinal, with an anticlinal axis a short distance to the west and with a synclinal depression on the east that was formerly occupied by an arm of the lake that once filled the upper Portneuf Valley.[13] He also refers to the age of the basalt and the character of the Pliocene deposits of the region.[14]

In the same year Orestes St. John, in charge of another Hayden party, traversed the eastern part of the reservation. He gives descriptions and geologic sections of the region north and northeast of Mount Putnam.[15]

The work of the members of the Hayden parties has been found to be correct in its general outlines. As may readily have been expected the work of the present party has served to supply a greater number of stratigraphic details and to call attention to the structural complexity of the region, which before was less clearly recognized.

[11] U. S. Geol. Survey Terr. Ann. Rept. for 1871, pp. 13–26, 1872.

[12] Bradley, F. H., [Report of the geologist of the Snake River division]: U. S. Geol. Survey Terr. Ann. Rept. for 1872, p. 206, 1873.

[13] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1877, pp. 563–569, 1879.

[14] Idem, pp. 640, 643.

[15] St. John, Orestes, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1877, pp. 325–338, 1879.

In addition to the men above noted, whose work concerned the immediate area of the reservation, a number of other writers may be cited who have touched upon problems more or less directly connected with the geology of the Fort Hall Reservation.

J. S. Newberry[16] gives an account of the Tertiary deposits of the general region of which the Fort Hall Indian Reservation is a part, in which he considers them as the products of great Tertiary lakes.

G. P. Merrill[17] gives a description and analysis of a sample of volcanic ash collected by Peale from the Pliocene deposits of the Portneuf Canyon. (See p. 117.) Dall and Harris[18] note the capping of basalt upon beds of the Salt Lake formation east of Snake River and north of the Portneuf, which lies within the area of the reservation.

Lindgren and Knowlton[19] discuss the Payette formation of the Boise district, which in many respects resembles the so-called Pliocene beds farther east but is referred by them to the upper Miocene. Knowlton later referred the Payette formation to the Eocene.[20]

Russell[21] discusses the Snake River lava and calls attention to the fact that it is for the most part younger than the Columbia River lava. In the Snake River district the latest eruptions probably occurred within historical times, perhaps not more than 100 to 150 years ago. The Columbia River lava is deeply weathered to a soft claylike soil 60 feet or more deep, but the lava of the Snake River plains is still fresh.

Bell[22] describes Tertiary lake deposits in the vicinity of Pocatello and the Portneuf Valley. He ascribes the deposits to a great lake which he calls Lake Idaho (this usage is probably independent of earlier usages). The deposits according to his statement have a vertical range of 4,000 feet.

Kindle[23] discusses the occurrence of Silurian and Devonian rocks in the region southeast of the Fort Hall Indian Reservation. These rocks also occur in the reservation, and much of his discussion is doubtless applicable to this region.

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[16] Newberry, J. S., The ancient lakes of western America: U. S. Geol. Survey Terr. Fourth Ann. Rept., pp. 329–339, 1871.

[17] Merrill, G. P., Notes on the composition of certain "Pliocene sandstones" from Montana and Idaho: Am. Jour. Sci., 3d ser., vol. 32, pp. 199–204, 1886.

[18] Correlation papers; Neocene: U. S. Geol. Survey Bull. 84, pp. 286–287, 1892. Refers to U. S. Geol. and Geog. Survey Terr. Fifth Ann. Rept., for 1871, p. 25, 1872.

[19] Lindgren, Waldemar, The mining districts of the Idaho Basin and the Boise Ridge, Idaho; with a report on the fossil plants of the Payette formation, by Frank H. Knowlton: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 625–736, 1898.

[20] U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), p. 3, 1904.

[21] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Survey Bull. 199, 1902.

[22] Bell, R. N., The origin of the fine gold of the Snake River: Eng. and Min. Jour., vol. 73, pp. 143–144, 1902.

[23] Kindle, E. M., The fauna and stratigraphy of the Jefferson limestone in the northern Rocky Mountain region: Bull. Am. Paleontology, vol. 4, No. 20, 1908.

The mining district in the vicinity of Pocatello is described by Weeks and Heikes[24] and by Bell.[25] A brief statement regarding this district is given in the present report on page 116.

J. P. Smith[26] in several papers gives an account of the marine Lower Triassic faunas of western America and their relationship to Asiatic and European faunas. He points out the lines of faunal migration[27] and describes the withdrawal of the Triassic sea, which was followed by the encroachment of the red beds.[28]

Girty[29] describes the fauna of the phosphate beds of the Park City formation, which are now separated out as a part of the Phosphoria formation.

Gale and Richards[30] and Richards and Mansfield[31] discuss the general geology and the phosphate deposits of neighboring regions.

Mansfield and Larsen[32] describe the occurrence and character of nepheline basalt in the Fort Hall Indian Reservation, and Mansfield[33] subdivides and discusses some of the Mesozoic formations of the same region.

STRATIGRAPHY.

GENERAL CHARACTER AND AGE OF THE ROCKS.

The rocks of the Fort Hall Indian Reservation include both sedimentary and igneous types. The sedimentary rocks present a rather full sequence from early Cambrian to Tertiary and Quaternary. Cretaceous rocks and some of the Tertiary formations are not present, but the other periods are all represented. Because of the sedimentary character of the phosphate deposits and their complex structural relation it was necessary to study the general stratigraphic

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[24] Weeks, F. B., and Heikes, V. C., Notes on the Fort Hall mining district, Idaho: U. S. Geol. Survey Bull. 340, pp. 175–183, 1908.

[25] Bell, R. N., Idaho State Insp. Mines Eighth to Fourteenth Ann. Repts., 1906–1912.

[26] Smith, J. P., The border line between Paleozoic and Mesozoic in western America: Jour. Geology, vol. 9, pp. 512–521, 1901; On the distribution of Lower Triassic faunas: Idem, vol. 20, pp. 13–20, 1912; The middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, 1914. Hyatt, Alpheus, and Smith, J. P., The Triassic cephalopod genera of the United States: U. S. Geol. Survey Prof. Paper 40, 1905.

[27] Smith, J. P., Jour. Geology, vol. 20, p. 19, 1912.

[28] Smith, J. P., U. S. Geol. Survey Prof. Paper 83, p. 4, 1914.

[29] Girty, G. H., The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah: U. S. Geol. Survey Bull. 436, 1910.

[30] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

[31] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 371–439, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[32] Mansfield, G. R., and Larsen, E. S., jr., Nepheline basalt in the Fort Hall Indian Reservation: Washington Acad. Sci. Jour., vol. 5, pp. 463–468, 1915.

[33] Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, pp. 31–42, 1916.

section of the region. Attention was centered, however, upon the phosphatic shales and the strata that succeed them, for it is upon the character and attitude of these rocks that the classification of the land as phosphate or nonphosphate must depend. The Tertiary and Quaternary rocks cover large areas and conceal many important stratigraphic and structural features. Indeed, the interpretation of the structure is in places rendered difficult or even impossible in the absence of borings by reason of this cover. Doubtless, too, it conceals valuable phosphate deposits, whose presence and quality can not be determined without drilling.

The igneous rocks include lavas, dikes, and fragmental deposits that cover large areas and add to the difficulties involved in stratigraphic and structural studies. They are particularly abundant in the northern part of the Bannock Valley region and the western part of the eastern mountainous region.

The general map (Pl. III) has been compiled from the individual township maps that were mostly worked on the field scale of 1:31,680. These maps have been reduced and adjusted to the topographic map that was prepared by C. G. Anderson on the field scale of 1:192,000 and enlarged to the scale of 1:125,000.

A tabular summary of the general stratigraphy of the reservation is given below. A more detailed description of the rock units is given in succeeding pages, for it is upon the recognition of the characteristics set forth in these descriptions that interpretations regarding stratigraphy and structure must rest.

Stratigraphic section of the Fort Hall Indian Reservation.

Geologic age.	Formation.	Thickness (feet).	General character.
Quaternary.		Not measured.	Alluvium, travertine, basalt, quartz latite, rhyolite.
Tertiary (Pliocene?).	Salt Lake formation.	Not measured.	Conglomerates, marls, and dense, nearly lithographic limestones and clays with interbedded volcanic ash and associated basalts, rhyolites, quartz latites, andesites, and tuffs. Except the lavas, these beds weather to a prevailingly white soil.
	Unconformity		
Jurassic.	Twin Creek limestone.	Estimated at not less than 2,500.	Yellow calcareous, fossiliferous sandstone with some beds of massive gray limestone. Laminated shaly gray limestone. Basal yellow calcareous sandstones, massive, with intercalated massive gray limestone that contains oyster shells.
	Unconformity?		
	Nugget sandstone.	Estimated at 1,500±.	Brick-red and light-colored sandstones.
	Unconformity?		

Stratigraphic section of the Fort Hall Indian Reservation—Continued.

Geologic age.		Formation.		Thickness (feet).	General character.
Triassic (?).		Wood shale.		200-250	Bright-red shale, weathering to red soil.
		Deadman limestone.		150±	Gray to purplish dense limestone of almost lithographic quality in some places; contains some gray and greenish chert.
		Higham grit.		500±	Coarse pink to white gritty or conglomeratic sandstone.
		Unconformity			
Lower Triassic.		Timothy sandstone.		800	Somewhat sugary yellowish to grayish sandstone in beds 1 to 3 inches thick, weathering with pinkish tinge.
		Unconformity(?)			
		Thaynes group.	Portneuf limestone.	1,500±	Siliceous, cherty gray to yellowish limestones in massive beds; contains rounded elongated nodules and streaks of chert; fossiliferous.
			Fort Hall formation.	800±	Yellowish and grayish limestones and sandstones. The limestones siliceous and cherty; the sandstones calcareous and fossiliferous.
			Ross Fork limestone.	1,350±	Dense gray nonfossiliferous thin-bedded limestone, olive-drab platy, calcareous shales, purplish gray thin-bedded and massive limestone that contains pelecypod and brachiopod faunas and ammonite zones near base.
		Woodside shale.		900	Olive-drab platy calcareous shales with interbedded reddish-brown limestones, more numerous near the top and crowded with pelecypods.
		Unconformity			
Carboniferous.	Permian.	Phosphoria formation.		500	Rex chert member about 350 feet thick (dark flinty shales, in some places massive chert; rarely grades into limestone).
					Phosphate shales about 150 feet thick (shales, impure limestone, and phosphate rock; main bed about 6 feet thick near base).
		Unconformity in places			
	Pennsylvanian.	Wells formation.		2,400±	Upper member, siliceous gray dense cherty limestone 50 feet or more thick; not well developed. Sandy beds not well exposed, thickness not known, perhaps 200-400 feet. Massive cherty gray limestone, fossiliferous; base not seen; thickness estimated at not less than 2,000 feet.
	Mississippian.	Brazer limestone.		Not measured.	Massive gray and drab limestones, fossiliferous; top and base not seen; stratigraphy and thickness not determined.
		Madison limestone.		Not measured.	Bluish-gray limestone beds, 1 to 8 inches thick, with intervening shaly bands 3 to 6 inches thick; fossiliferous; top and base not seen.

Stratigraphic section of the Fort Hall Indian Reservation—Continued.

Geologic age.		Formation.	Thickness (feet).	General character.
Devonian.		Threeforks (?) limestone. Jefferson limestone.	Not measured.	Dark-gray massive limestones, more or less broken; sparingly fossiliferous. Identified by fossil collections and stratigraphic position.
Silurian.		Laketown dolomite.	Not measured.	Yellowish-brown to gray dolomitic limestone that contains imperfectly preserved silicified fossils. Identified by a single fossil collection.
Ordovician.		Fish Haven dolomite.	Not measured.	Gray to brown weathering dark dolomitic limestone commonly much shattered and veined, somewhat cherty; contains Richmond fossils.
		-Unconformity-		
		Swan Peak quartzite.	Estimated at 500.	White dense vitreous quartzite; a conspicuous cliff maker. Of Chazy (?) age.
		Garden City limestone.	Not measured.	Gray limestone, very cherty; chert forms rough surfaces and weathers reddish brown; in some localities the rock is bluish gray, relatively pure, and sparingly fossiliferous; of Beekmantown age.
Cambrian.	Upper and Middle Cambrian.	Formations not differentiated.	Not measured.	Dark-gray limestone that contains yellow sandy or cherty streaks and shows annelid trails; some beds are oolitic and contain brachiopods, trilobites, and other fossils. Also massive gray well-crystallized beds that weather brown; shales and some sandstone are also present. Formations not differentiated from each other nor everywhere differentiated from overlying Ordovician.
	Middle and Lower Cambrian.	Brigham quartzite.	Estimated not less than 1,000.	Reddish to purplish and pink dense siliceous quartzites, including gritty and conglomeratic facies.

CAMBRIAN SYSTEM.

The Cambrian system is well developed in the Fort Hall Indian Reservation. Although it was not practicable to differentiate and map the individual formations, much similarity was noted between the sections there exposed and the sections at Blacksmith Fork, Utah, and west of Liberty, Idaho, in the Montpelier district, described by Walcott. The section at Liberty is given here for comparison.[34]

[34] Walcott, C. D., Cambrian section of the Cordilleran area: Smithsonian Misc. Coll., vol. 53, pp. 6–9, 190–200, 1908.

Section of Cambrian strata on Mill Creek, west of Liberty, Idaho.

Series.	Formation.	Thickness (feet).	General character.
Upper Cambrian.	St. Charles formation.	1,197	Bluish-gray to gray arenaceous limestones, with some cherty and concretionary layers, passing at the base into thin-bedded gray to brown sandstone.
Middle Cambrian.	Nounan formation.	814	Light-gray to dark lead-colored arenaceous limestones.
	Bloomington formation.	1,162	Bluish-gray, more or less thin-bedded limestones and argillaceous shales; small rounded nodules of calcite are scattered irregularly through many of the layers of limestone.
	Blacksmith formation.	23	Gray arenaceous limestones in massive layers.
	Ute formation.	731	Blue to bluish-gray thin-bedded fine-grained limestones and shales, with some oolitic concretionary and intraformational conglomeratic layers.
	Spence shale [member of Ute limestone].	30	Argillaceous shales.
	Langston formation.	30	Massive bluish-gray limestone with many rounded concretions.
	Brigham formation.	1,000+	Massive quartzitic sandstones.

The St. Charles limestone is probably represented by some of the cherty gray limestones west of the quartzite hills in T. 4 S., R. 36 E., and perhaps on the north side of Mount Putnam in T. 5 S., R. 37 E. At the former locality a sandstone is associated with the limestones that may correspond with the Worm Creek quartzite member at the base of the St. Charles.

The Bloomington formation may be represented by the limestone just west of the narrows of Ross Fork Canyon in sec. 11, T. 5 S., R. 36 E. Here the limestone at the base corresponds lithologically to the Blacksmith limestone, which lies beneath the Bloomington, and limestone and shales follow below.

The Blacksmith limestone appears to be represented at a number of places.

Other limestones, some of them oolitic and containing intraformational conglomerates together with shales, come in near the massive quartzites, which with little doubt represent the Brigham quartzite.

The Brigham quartzite forms much of the exposed rock in the high country about North Putnam and South Putnam mountains. It is prevailingly dense, vitreous, iron-stained, reddish or purplish,

and in many places gritty or conglomeratic. It has not been measured but is doubtless 1,000 feet or more thick. (See Pl. I, *A*, *C*, p. 16.)

The formations between the Brigham quartzite and the Swan Peak quartzite have been grouped in the mapping, the Garden City limestone and Upper Cambrian being mapped together and the remainder of the Cambrian being shown by a separate color pattern. The thickness of these rocks has not been determined but may be comparable to that given in the above section.

ORDOVICIAN SYSTEM.

GARDEN CITY LIMESTONE.

The Garden City limestone has not been differentiated on the map from the Upper Cambrian rocks. A number of fossil collections from it have been identified by Edwin Kirk, from localities along the west front of the quartzite hills in Tps. 4 S. and 5 S., R. 36 E.; secs. 25 and 28, T. 8 S., R. 33 E.; and doubtfully elsewhere. The following fossils have been identified by Edwin Kirk:

Locality Mt. 8, NW. ¼ NW. ¼ sec. 25, T. 8 S., R. 33 E.
- Dalmanella cf. D. pogonipensis (Hall and Whitfield).
- Maclurea cf. M. subannulata Walcott.
- Asaphellus sp.
- Crinoid and cystid fragments.

Locality Mt. 19, SE. ¼ SE. ¼ sec. 28, T. 8 S., R. 33 E.
- Maclurea sp.
- Crinoid fragments.

Locality M. 270, SE. ¼ NW. ¼ sec. 27, T. 4 S., R. 36 E.
- Asaphellus sp.
  - Probably same horizon as Mt. 8.

Locality M. 272, NW. ¼ SW. ¼ sec. 23, T. 4 S., R. 36 E.
- Sponge?
- Crinoid stems.

The rock is dark-gray limestone which contains much chert that weathers with rough surface, the chert becoming reddish. The fauna indicates Beekmantown age.

SWAN PEAK QUARTZITE.

The Garden City limestone is overlain by a dense white vitreous quartzite, called the Swan Peak quartzite, by correlation with the section of the Randolph quadrangle, Utah, that has been described by Richardson.[35] The rock is quite uniform in character and is only rarely conglomeratic. In places the quartzite shows cross-bedding and tubular cavities or linear markings suggestive of worm borings. The quartzite was not measured but is estimated to be about 500 feet

[35] Richardson, G. B., The Paleozoic section in northern Utah: Am. Jour. Sci., 4th ser., vol. 36, pp. 406–416, 1913.

thick. It is a conspicuous cliff maker and forms rugged topography. It constitutes the summit of North Putnam Mountain and of the quartzite hills north of Ross Fork Creek in Tps. 4 and 5 S., R. 36 E. (See Pl. I, *C*.) It also appears west of Bannock Peak in T. 9 S., R. 32 E.; in Rattlesnake Canyon, T. 8 S., R. 33 E.; in sec. 20, T. 5 S., R. 38 E., and elsewhere. Its vitreous, brittle character has caused it to be much fractured by the deformation to which it has been subjected, and it is commonly slickensided and iron stained. The abundance of its large fragments in the Tertiary deposits suggests that extensive masses of it are now concealed by this later cover or that overthrust or infolded areas of it, more extensive than those now remaining, have been removed by erosion. The Swan Peak quartzite is of Lower Ordovician (Chazy?) age.

FISH HAVEN DOLOMITE.

Above the Swan Peak quartzite is a series of dark-gray limestones correlated with the Fish Haven dolomite of the Randolph quadrangle, Utah, classified by Richardson.[36] The rocks are somewhat cherty. They weather light gray or brown, with a purplish tinge, and are usually much fractured and seamed with calcite. The chert appears in small round and irregular white or bluish nodules. The top of the formation has not been recognized, and no measurements of thickness have been made. Several collections of fossils have been identified by Edwin Kirk, as follows:

Locality Mt. 24, SW. ¼ sec. 1, T. 9 S., R. 33 E.
- Trochonema sp.
- Halysites gracilis Hall.
- Streptelasma sp.

Locality M. 30, NW. ¼ NW. ¼ sec. 36, T. 9 S., R. 33 E.
- Rhynchotrema perlamellosa (Whitfield).
- Dalmanella cf. D. meeki (Miller).
- Plectorthis cf. P. whitfieldi (Winchell).
- Streptelasma rusticum (Billings).

Locality M. 105, sec. 12, T. 5 S., R. 36 E.
- Streptelasma.

Locality M. 162, sec. 20, T. 5 S., R. 38 E.
- Rafinesquina sp.
- Streptelasma sp.

Locality M. 237, sec. 24, T. 4 S., R. 36 E.
- Halysites gracilis Hall.

Kirk states that the fossils are of Richmond age. The Fish Haven dolomite forms rugged ridges, as along the east boundary of T. 4 S., R. 36 E., where it is intensely shattered. The Ordovician and Cambrian rocks underlie the surface of the higher and rougher country

[36] Richardson, G. B., op. cit.

in the vicinity of North and South Putnam mountains and in the southern part of the Bannock Valley region.

SILURIAN SYSTEM.

LAKETOWN DOLOMITE.

The occurrence of Silurian rocks in the Fort Hall Indian Reservation is known from a single collection of fossils. The fragments that were collected at locality Mt. 37, SW. ¼ SW. ¼ sec. 24, T. 9 S., R. 33 E., were chiefly of one form, which was identified by Edwin Kirk as *Conchidium* sp., doubtfully Silurian. The rock is correlated with Laketown dolomite (Silurian) of the Randolph quadrangle, Utah, described by Richardson.[37] The extent and thickness of the beds have not been determined. The rock is a yellowish-brown limestone and contains abundant silicified fragments of fossils. The locality from which the collection was taken is a knoll just east of the big quartzite hill east of Bannock Valley.

DEVONIAN SYSTEM.

JEFFERSON LIMESTONE.

The presence of the Jefferson limestone is known from a single collection of fossils, Mt. 31, NW. ¼ NW. ¼ sec. 23, T. 9 S., R. 33 E. From this locality Edwin Kirk has identified two forms—*Stromatopora* sp. and Bryozoa (?).

The rock is a dense fine-grained black limestone, interbedded with dark-gray banded, dark-gray mottled, and light-gray fine-grained limestone. The thickness and extent of the formation have not been determined.

THREEFORKS (?) LIMESTONE.

Fossils of doubtful Threeforks age have been collected from two localities. Edwin Kirk has identified the following forms:

Locality M. 133, NE. ¼ SE. ¼ sec. 29, T. 5 S., R. 38 E.
- Atrypa reticularis Linné.
- Spirifer cf. S. disjunctus Sowerby.

Locality M. 297, sec. 12, T. 4 S., R. 36 E.
- Camarotoechia sp.
- Spirifer sp.
- Bucanopsis sp.

The rocks are massive bluish-gray limestones. Their extent and thickness have not been determined. In the range east of Bannock Valley in T. 9 S., R. 33 E., it has not been practicable to differentiate Devonian and Silurian rocks from the lower Carboniferous above nor from the Ordovician limestone below. In this locality the prephosphate rocks are grouped and mapped as undifferentiated Paleozoic.

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[37] Richardson, G. B., op. cit.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

MADISON LIMESTONE.

The Madison limestone, of lower Mississippian age, as represented in the Fort Hall Indian Reservation, is a relatively thin-bedded dark bluish gray limestone, that forms beds 1 to 8 inches thick, and contains intervening shaly beds 3 to 6 inches thick in some places. Some exposures show a rock of lighter color and in more massive beds. The formation occurs in a number of widely separated localities, including the rocky hill in the NW. ¼ sec 18, T. 4 S., R. 37 E.; several places in the ridge in the west part of T. 5 S., R. 38 E.; east of Bannock Valley along the line between Tps. 8 and 9 S., R. 33 E.; and in the vicinity of Bannock Peak, in T. 9 S., R. 32 E. The top and base of the formation have not been recognized nor the extent and thickness determined. The rocks, however, appear to occupy relatively small areas in some of the more rugged parts of the reservation, where they have been exposed by the erosion of faulted or folded strata. Fossils are rather numerous and include small cup corals, gastropods, spiriferoid and other brachiopods, trilobite fragments, and crinoids, which have been identified by G. H. Girty as characteristic of the Madison limestone. The formation as exposed on the reservation shows no unusual facies but appears to be similar to rocks of the same age in other parts of the Idaho field as described in previous reports.[38] According to G. H. Girty, the Madison fauna is of lower Mississippian age and corresponds to that of the basal portion of the "Wasatch limestone" of the Wasatch Mountains of Utah, as described by the early writers.

BRAZER LIMESTONE.

The upper Mississippian rocks of the Fort Hall Indian Reservation are referred to the Brazer limestone by correlation with the section of the Randolph quadrangle, Utah, described by Richardson.[39] The relations of the Brazer limestone to the Madison limestone have not been worked out, for the contact region has not been studied. In parts of the southeastern Idaho field previously studied the two formations are apparently conformable. Like the Madison, the Brazer is associated with rugged hills in widely separated parts of

[38] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 473–474, 1910.
Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 383–384, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[39] Richardson, G. B., op. cit.

the area. The Brazer is associated with the Madison at a number of the localities above mentioned. Its most extensive occurrence is in the ridge along the boundary between T. 9 S., R. 32 E., and T. 9 S., R. 33 E. The rocks are massive dark-gray to light-gray limestones, somewhat cherty but on the whole rather pure. The chert occurs in both streaks and nodules, and there are streaks or veinlets of calcite or aragonite. In some places the rock is finely crystalline and contains many crinoid stems. The extent and thickness of the formation have not been determined, but the thickness in the Bannock Valley district is probably not less than 800 to 1,000 feet. Some horizons are abundantly fossiliferous. The fauna includes *Productus giganteus*, *Syringopora*, *Schizophoria*, *Moorefieldella*, Bryozoa, and large cup corals with many fine septa, together with other forms. The formation presents no unusual facies, but agrees very well with descriptions given in the reports that have been cited.

In these accounts the similarity has been pointed out between the upper Mississippian fauna and the Spergen fauna identified by Meek from the divide between Ross Fork and Lincoln Valley. An attempt was made by G. H. Girty and members of the party to rediscover the locality in which the fauna identified by Meek occurred. It was found, however, that the descriptions of the locality were inadequate and that the locality probably lay outside of the Ross Fork drainage basin and outside the limits of the reservation.

PENNSYLVANIAN SERIES.

WELLS FORMATION.

The Brazer limestone is succeeded by about 2,400 feet of more or less siliceous and cherty limestone that contains sandy or quartzitic beds. This limestone is correlated with the Wells formation of the Montpelier quadrangle, Idaho, that has been described by Richards and Mansfield.[40] The base of the formation has not been seen, but in sec. 6, T. 4 S., R. 37 E., where the lower Wells adjoins the Brazer limestone, there has been considerable disturbance of the strata, probably involving faulting. Blackwelder[41] has reported an unconformity between the Pennsylvanian and Mississippian in Utah, but no such relationship has yet been recognized in the southeastern Idaho field.

In the type locality the Wells consists of three fairly well defined parts—limestone below and at the top and sandstones and quartzites in the middle. The formation as a whole is highly siliceous. The lower limestones are cherty and contain numerous sandy beds. The

[40] Richards, R. W., and Mansfield, G. R., The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, pp. 681–709, 1912; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey B—ll 577, 1914.

[41] ·ckwelder, Eliot, New light on the geology of the Wasatch Mountains, Utah: c. America Bull., vol. 21, p. 530, 1910.

middle sandstone member weathers down largely to smooth slopes, on which lie rounded sandstone débris. The upper limestone is dense and siliceous, and bluish chert bands become more numerous and conspicuous toward the top. There is, too, a considerable fauna in the limestones. At the top the Wells is in some places unconformable beneath the overlying Phosphoria formation.

In the Fort Hall Indian Reservation the Wells maintains the above general characteristics but with some modifications. The lower limestone has increased to a thickness of about 2,000 feet and contains massive cherty limestones and some alternating beds of sandstone or quartzite. The middle sandstones, if present, are probably reduced in thickness and largely concealed beneath weathered slopes and later deposits. The thickness of the beds that occupy this interval is estimated at 200 to 400 feet. The upper limestone is prominent in some places, as in secs. 10 and 11, T. 4 S., R. 37 E., and sec. 36, T. 5 S., R. 38 E., where it is 50 feet or more thick, but elsewhere it is rather poorly developed. In some places there has been dislocation in the beds at that horizon, as in sec. 17, T. 5 S., R. 38 E., but in others the lack of development may be due to unconformity as probably in sec. 21, T. 4 S., R. 37 E.

The lower part of the formation is composed of dark bluish-gray limestone with chert in nodules and irregular streaks. Above this cherty limestone come yellowish and grayish sandy limestones, some of them in thin layers so arranged as to make massive ledges. Near the top of this limestone series the rocks are again gray and cherty.

The upper limestone series is very light in color and sandy. The chert near the top occurs in dark bands, in some places 4 to 6 inches thick, that are black rather than bluish and resemble some facies of the Rex chert. The rock is hard but not so fine textured and dense as in the region of the type locality. Also the absence of little silicified and crescentic fragments of brachiopods like those that project from weathered surfaces in the type locality is noteworthy here.

A red-bed layer is included in the Wells formation in sec. 15, T. 5 S., R. 35 E. Its stratigraphic position is probably in the sandy upper middle portion of the formation, but this could not be determined with certainty. It is apparently underlain by dark-gray fossiliferous limestones, which are assigned by G. H. Girty to the Wells.

Fossils occur at different horizons throughout the limestones but are more abundant in the lower part. The occurrence of *Fusulina* near the middle of the lower limestone series is noteworthy. Large cup corals, abundant Bryozoa, colonies of *Springopora*, *Spirifer rockymontanus*, and other forms were observed. One of the colonies of *Syringopora* measured 3 by 2 feet.

The Wells formation, like the Brazer and Madison limestones, occurs in widely separated districts in the eastern mountainous region

and in the Bannock Valley region. The most extensive area lies in the northwest part of T. 4 S., R. 37 E., where the formation comprises the core of a large anticline that is somewhat complicated by faulting and minor folding. This area was studied by G. H. Girty and J. W. Merritt, but they found that a detailed stratigraphic section was not feasible.

PERMIAN SERIES.

PHOSPHORIA FORMATION.

Occurrence.—The Phosphoria formation, which represents the upper two members of the Park City formation as mapped in southeastern Idaho, southwestern Wyoming, and northeastern Utah in the reports for 1909 and 1910, has been described in previous papers.[42] It accompanies the Wells formation in the eastern mountainous district of the reservation but has not been recognized in the Bannock Valley region. The Phosphoria formation is exposed only in parts of four townships—T. 4 S., R. 37 E.; T. 4 S., R. 38 E.; T. 5 S., R. 37 E.; and T. 5 S., R. 38 E.—although float pieces of phosphate rock are found in parts of neighboring townships. The detailed distribution of the formation is shown on the large-scale maps that accompany the descriptions of those townships (pp. 83–91, 95–103).

Phosphate shales.—The phosphate shales, which constitute the lower member of the formation, are slightly exposed in the NE. ¼ NE. ¼ sec. 11, T. 4 S., R. 37 E., along the west side of a ravine. Also on low rocky points in the NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., the SE. ¼ SE. ¼ sec. 21, T. 4 S., R. 37 E., and in the NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., the phosphate float is so abundant as to amount practically to a slight exposure of the shales. It has not been practicable to make a complete section across the phosphate shales, but numerous paced measurements have been made across the belt occupied by float, the distance measured being that between the highest phosphate float and the highest float of the Wells formation. These measurements show some variations, but allowing for the angle of dip the shales appear to be about 150 feet thick. The thickness is thus comparable to that of the shales examined in the Montpelier and Georgetown districts farther southeast.

The fauna of the phosphate shales is somewhat extensive, although fossils are relatively rare in the beds of phosphate rock. G. H. Girty notes that the fauna presents an unusual and distinctive facies. He has selected from the forms described in his bulletin[43] the following list as characteristic:

[42] Richards, R. W., and Mansfield, G. R., The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, pp. 681–709, 1912; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[43] Girty, G. H., The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah: U. S. Geol. Survey Bull. 436, 1910.

Lingula carbonaria?
Lingulidiscina missouriensis.
Chonetes ostiolatus.
Productus geniculatus.
Productus eucharis.
Productus montpellerensis.
Productus phosphaticus.
Pugnax weeksi.
Pugnax osagensis var. occidentalis.
Ambocoelia arcuata.
Leda obesa.
Plagioglypta canna.
Omphalotrochus ferrieri.
Omphalotrochus conoideus.
Hollina emaciata var. occidentalis.

In the NE. ¼ NE. ¼ sec. 21, T. 4 S., R. 37 E., there is a bed of phosphate rock at the base of the shales, about 8 inches thick, which is composed largely of the fragments of shells. This bed was originally composed largely of carbonate of lime but is now apparently phosphatized, for an analysis of the rock shows the presence of 33.9 per cent of phosphorus pentoxide, equivalent to 74 per cent of tricalcium phosphate. This rock contains in addition large numbers of linguloid and discinoid shells and some pieces of bone. A fish spine was also found in the middle of the main phosphate bed in sec. 36, T. 5 S., R. 38 E.

Three partial sections of the phosphate shales were measured in trenches and test pits excavated by the Survey party. No other openings had been made in these deposits in the reservation. The sections in these openings and the percentage of phosphorus pentoxide contained in the samples that were taken are given in the following tables:

Partial section of phosphate shales in NE. ¼ NE. ¼ sec. 13, T. 5 S., R 37 E., about 20 feet from section corner.

Character of beds.	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.	
	Per cent.	Per cent.	Ft.	in.
Shale, brown to light, sandy, broken, top not exposed.				
Phosphate rock, black, fine grained, hard, cherty (?)			1	3
Broken zone, shale and phosphate rock, brown to black			1	8
Phosphate rock, dark brown, finely oolitic, somewhat shaly, much broken, with interbedded shale			2	8
Shale, phosphatic, black to brown, with a few narrow bands of phosphate, much broken			4	9
Broken zone, mingled phosphate rock and shale, brown to yellowish			1	3
Phosphate rock, fine to coarse oolitic texture, beds up to 3 inches thick, dark gray to black, weathering yellowish, and in broken blocks coated white, including— *Inches.*				
Sample 5 ... 22	34.65	75.71		
Sample 4 ... 22	34.59	75.57	5	6
Sample 3 ... 22	32.64	71.31		
Phosphate rock, medium oolitic, brownish gray, with a few yellow sandy streaks; beds have a maximum thickness of 1½ inches, grading into thin shaly phosphate (sample 2)	23.98	52.31	1	5
Shale, yellowish brown, finely banded, iron stained, much broken and containing scattered phosphate nodules and streaks			2	6
Chert, with phosphatic nodules and fragments of discinoids, much broken				10
Shale, yellowish brown, sandy, with irregular phosphate streaks			3	0
Phosphate rock, medium to fine, oolitic; contains yellow sandy streaks (sample 1)	22.97	50.18	1	5
Sandy beds, yellowish brown, scattered phosphate nodules, banded, chert, black, broken; base not seen				6

Partial section of phosphate shales in NW. ¼ NE. ¼ sec. 11, T. 4 S., R. 37 E., compiled from trench and three test pits.

Character of beds.		P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness. Ft.	in.
		Per cent.	Per cent.	Ft.	in.
Shales, black and purplish; base and top not exposed				2	6±
Not exposed				15±	
Sandy and shaly material, yellow; base and top not exposed				2	6
Not exposed				50±	
Limestone, black, fetid					8
Phosphate rock, irregularly bedded, black, nodular				1	0
Shale, brownish black; base not exposed				1	6
Not exposed				20	0
Shale, black, thin-bedded, top not exposed				1	0
Broken zone that contains fragments of phosphate rock and shale, much weathered, and calcareous material					6
Phosphate rock, broken, somewhat sandy, weathered; has a calcareous coating and a medium to coarse oolitic texture					3
Phosphate rock, medium to coarse, oolitic toward top, black to brown; white coating along bedding planes and joint surfaces; beds one-eighth of an inch to 3 inches thick including—	Inches.				
Sample 3	28	34.35	75.05		
Sample 2	24	34.22	74.77	6	4
Sample 1	24	32.62	71.47		
Phosphate rock, medium oolitic, thin-bedded, yellow, sandy streaks, white calcareous streaks, much broken and weathered				1	3
Fault, small, normal, plane vertical, downthrow on north, throw not shown but probably slight as same yellow material that occurs on south side lies under phosphate on north side.					
Broken sandy material that contains fragments of black chert and a few pieces of phosphate.					
				102	6

Partial section of phosphate shales in NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., compiled from trench and six test pits.

Character of beds.	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness. Ft.	in.
	Per cent.	Per cent.	Ft.	in.
Soil and other material.				
Shale, broken pieces, black to brown, somewhat phosphatic; contains small lenses and scattered oolites			2±	
Not exposed			48	
Soil and other material			1	0
Shale, brown			1	0
Not exposed			7	0
Soil that contains fragments of cherty limestone and shale			18±	
Phosphate rock layer, black, medium oolitic				1
Shale, black				7
Not exposed			16	
Limestone, deep drab				3
Shale, brown, with scattered oolites				3
Phosphate rock, black, medium oolitic				2
Shale, brown; base not shown			1	0
Not exposed			10	0
Phosphate rock, black, finely oolitic	31.40	68.7	1	9
Shale, brown				6
Not exposed			10	0
Shale, black, phosphatic			1	0
Not exposed			15	0
Limestone, scattered oolites				3
Shale, black, weathered brown			2	11
Limestone, black, fetid, fossiliferous; "Cap lime"			2	1
Main bed of phosphate rock, oolitic	33.02	72.1	2	1
	35.46	77.4	2	0
	33.14	74.1	2	0
Phosphate rock, sandy				6
Zone, weathered, yellow, sandy				9
Phosphate rock, hard, dense				3
Limestone, lower Phosphoria, fossiliferous.				
			146	5

The three sections all show the presence near the base of a phosphate bed 5 or 6 feet thick which contains on the average more than 70 per cent tricalcic phosphate. Much phosphatic material is distributed through the shales above the main phosphate bed, and at least one other bed of workable thickness and of nearly 70 per cent quality is shown in the section in T. 5 S., R. 38 E. In the Georgetown district still another bed of workable thickness and quality is shown near the top of the shales. This bed is usually difficult to open because of the large and abundant fragments of Rex chert that conceal the upper portion of the shale. It is possible that this bed is represented in the Fort Hall Indian Reservation, but its presence was not determined.

The "Cap lime" was present in only one of the three sections examined—that in T. 5 S., R. 38 E. Its absence in the other two sections may, perhaps, be due to the disturbance indicated by the broken zone above the main phosphate bed in those sections.

The fossiliferous limestone at the base of the section in T. 5 S., R. 38 E., was noted at only two other places besides the place where the section was measured—in the NW. ¼ NW. ¼ sec. 36, T. 5 S., R. 38 E., and the SE. ¼ SE. ¼ sec. 21, T. 4 S., R. 37 E. The rock is dark and fetid and contains large forms of *Productus* and *Spirifer*. The thickness was not determined but probably does not exceed 2 or 3 feet.

Rex chert member.—The Rex chert member, which overlies the phosphate shales, is represented chiefly by a dark, flinty shale that forms rounded hills and smooth slopes strewn with small angular fragments. In some places, as in secs. 2 and 11, T. 4 S., R. 37 E., and sec. 28, T. 5 S., R. 38 E., the Rex forms characteristic dark massive ledges of chert, and in one place, in the SE. ¼ SW. ¼ sec. 29, T. 5 S., R. 38 E., the chert appears to grade into a massive cherty limestone.

An unusual facies was observed by G. H. Girty and J. W. Merritt in the SW. ¼ NW. ¼ sec. 2, T. 4 S., R. 37 E. Here the rock is a yellow sandy shale and carries beds of earthy limestone. Its lithology is similar to Woodside shale though of somewhat more intense yellow color. The distinguishing feature is the presence of a distinctly Paleozoic fauna, which consists chiefly of the brachiopod *Ambocoelia* in abundance, together with pelecypods that suggest Paleozoic characteristics but are not definitely identified.

The Rex chert is generally nonfossiliferous, but at some places it contains spicules and casts of crinoid stems, in addition to brachiopods. G. H. Girty lists the following as the most characteristic species:

Productus multistriatus.
Productus subhorridus.
Spirifer aff. S. cameratus.
Spiriferina pulchra.
Composita subtilita var.

At a locality on Deer Creek, in the Preuss Range, Mr. Girty obtained the following fauna from the limestone facies of the Rex chert:

Amphoporella laminaria.
Productus nevadensis.
Productus eucharis.
Productus multistriatus?
Camarophoria n. sp.

No fossils were found in the Rex chert in the Fort Hall Indian Reservation.

At two or three places in the ridge in the west part of T. 5 S., R. 38 E., there are small areas of a grayish-yellow chert, more or less brecciated and associated with a light-gray limestone.

The identity of this chert is in doubt. It may be assignable to the Rex or perhaps to the Wells formation.

The thickness of the Rex chert, as measured in a section that includes Triassic beds, in secs. 1 and 2, T. 4 S., R. 37 E., is 350 feet.

TRIASSIC SYSTEM.

OCCURRENCE AND SUBDIVISIONS.

The Triassic system is well represented in the eastern mountainous region of the Fort Hall Indian Reservation, where it has been subdivided into five formations that aggregate 5,350 feet in thickness, classed as Lower Triassic. In addition three formations of somewhat uncertain age, which have a combined thickness of 900 feet, are doubtfully classified as Triassic. The Lower Triassic rocks are not exposed elsewhere in the reservation. The five formations into which they are divided are the Woodside shale, Ross Fork limestone, Fort Hall formation, Portneuf limestone, and Timothy sandstone. The Ross Fork, Fort Hall, and Portneuf comprise the Thaynes group. The three doubtfully Triassic formations are the Higham grit, Deadman limestone, and Wood shale. The Nugget sandstone, which overlies the Wood shale and was formerly considered as Triassic or Jurassic, is now referred to the Jurassic.

REVIEW OF NOMENCLATURE.

The names of some of the subdivisions mentioned in the preceding paragraph are comparatively new, and others are used in a somewhat different sense from that in which they have hitherto been employed, so that an outline of the steps by which these changes in nomenclature have come about may appropriately be given here.

The Woodside shale and Thaynes formation were first described by Boutwell[44] in the Park City district of Utah. He also described

[44] Boutwell, J. M., Stratigraphy and structure of the Park City mining district, Utah: Jour. Geology, vol. 15, pp. 434–458, 1907.

an overlying formation, chiefly of red beds, 1,650 feet thick, which he called the Ankareh shale. About the same time Veatch[45] described formations in southwestern Wyoming to which he gave Boutwell's names Woodside and Thaynes, but he also described a series of sandy beds above these, 1,900 feet thick, to which he gave the name Nugget formation. The lower 600 feet of the Nugget formation was described as made up of bright-red sandstones and shales, and the upper 1,300 feet as yellow thin-bedded sandstones and shales that weather dark brown. The two subdivisions were mapped separately by Veatch.

Gale and Richards[46] and later Richards and Mansfield[47] carried the nomenclature of Boutwell and Veatch into southeastern Idaho, employing the name Ankareh shale for the red beds above what was then regarded as the upper limestone of the Thaynes and below a conglomeratic sandstone near the base of the Nugget as exposed in Raymond Canyon, in the Montpelier quadrangle.

Boutwell[48] in a latter publication employed Veatch's term Nugget to designate the upper 500 feet of the beds which he had formerly included in his Ankareh shale.

The examination of the Fort Hall Indian Reservation in 1913 led the present writer to consider the Thaynes a group of three formations, the uppermost of which, now known as the Portneuf limestone, has an abundant and distinctive fauna and is about 1,500 feet thick. The rocks representing the Nugget sandstone of Veatch were also divided by the writer into four members, the lowest of which is a massive conglomeratic sandstone 500 feet thick, supposed to correspond with the conglomeratic sandstone at the Raymond Canyon section. Between the Portneuf limestone and this conglomerate there is a sugary yellowish sandstone 800 feet thick that was supposed to correspond stratigraphically with the Ankareh shale, though it contains no red beds, and this was called the Ankareh sandstone.[49]

The subdivisions as worked out in the Fort Hall Indian Reservation were carried eastward in succeeding field seasons into the Lanes Creek and Freedom quadrangles and thence southward into the Montpelier quadrangle and some of the regions formerly studied by

[45] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, pp. 50–56, 1907.

[46] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

[47] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 371–439, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[48] Boutwell, J. M., Geology and ore deposits of the Park City district, Utah: U. S. Geol. Survey Prof. Paper 77, pp. 42–59, 1912.

[49] Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hill Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, pp. 31–42, 1916.

Gale and Richards. The Portneuf limestone is divisible into three members, a lower and upper limestone, each of which carries a similar fauna, and a well-developed intervening red member consisting of interbedded sandstones and shales. The red member thickened southward whereas the upper limestone grew thinner in that direction. The upper limestone member of the Portneuf is believed to be the "limestone or calcareous shale" mentioned by Gale and Richards[50] as composing the upper member of their Ankareh shale, and the underlying "red bed" member of the Portneuf is believed to compose the lower member of their Ankareh shale, whereas the lower limestone of the Portneuf constitutes the top member of their Thaynes. The relationships here outlined are shown in the accompanying table.

If the subdivisions Portneuf, Timothy, Higham, Deadman, and Wood are to be retained, as seems desirable because of the detailed work in which they have been employed, the term Ankareh must be dropped from the nomenclature of southeastern Idaho. The retention of the name Ankareh for the sugary-yellow sandstone above the Portneuf limestone is inadvisable, both because of the difference in lithology and because the sandstone represents only a small part of the stratigraphic interval to which the name was originally applied. A new name, Timothy sandstone, is therefore here adopted for this sandstone.

The "main sandstone member of the Nugget," as it was previously called in the Fort Hall Indian Reservation,[51] is distinct and characteristic wherever exposed. It is recognized as a distinct mappable unit over a large area, for it is the same as the Nugget sandstone of Boutwell in the Park City district, Utah, the same as the Nugget sandstone of Schultz in the Rock Springs uplift of southwestern Wyoming, and the same as the upper member (major part) of Veatch's Nugget formation, as typically exposed at Nugget station, on the Oregon Short Line Railroad, in Lincoln County, southwestern Wyoming. Accumulated evidence supports the view that it is of Jurassic age. The name Nugget is therefore here restricted to this sandstone. The lower 600 feet of Veatch's Nugget, comprising his "red-bed member," is regarded by both the writer and Mr. Schultz, who has studied the rocks at the Nugget type locality, as the equivalent of the Higham grit, Deadman limestone, and Wood shale of the Fort Hall Indian Reservation, and there is no reason why they should be grouped with the overlying beds, for they are lithologically and stratigraphically distinct.

The Higham grit, separated from the underlying formations by a marked unconformity, and the succeeding Deadman limestone and

[50] U. S. Geol. Survey Bull. 430, p. 480, 1910.

[51] Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, *Mesozoic*, in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, p. 42, 1916.

.thwestern Wyoming.

Mansfield. ɔrt Hall Indian Reservation and neighboring areas in southeastern Idaho. [g]			Schultz. Rock Springs uplift, southwestern Wyoming. [h]	Age.
ʷin Creek limestone, 2,500–3,000± feet.			Twin Creek limestone.	Jurassic.
ugget sandstone (red and light-colored sandstones).			Nugget sandstone.	
ʻood shale (red).			Ankareh shale.	Triassic (?).
eadman limestone.				
igham grit.				
imothy sandstone (yellowish).			Not recognized.	Lower Triassic.
ıaynes ;roup, ,600 feet.	Portneuf limestone.	Limestone.	Thaynes (?) formation.	
		Red sandstones and shales, 200–1,000 feet.		
		Limestone.		
	Fort Hall formation.			
	Ross Fork limestone.			
ʳoodside shale.			Woodside shale.	

ɫ there is an unconformity at the base of the Nugget there, and that the Higham grit will be found
ɔe is probably not represented in Veatch's section.

Wood shale are also here treated as independent formations because they have been identified and mapped over considerable areas in the Cranes Flat, Lanes Creek, Freedom, and Montpelier quadrangles as well as in the Fort Hall Indian Reservation.

LOWER TRIASSIC FORMATIONS.

GENERAL CHARACTER.

The formations assigned to the Lower Triassic include 5,350 feet of shales, calcareous beds, and sandstones grouped in five formations, all of which except the Timothy sandstone are fossiliferous at certain horizons. The determination of age, as pointed out in the discussion of the Ross Fork limestone, is based upon ammonite zones, which here occur 900 to 1,200 feet above the top of the Paleozoic formations. The fossils of the overlying 4,000 feet of sediments are less distinctive, and the faunal relations of some of them, notably certain brachiopods of the Portneuf limestone, have not been fully studied. It is therefore possible, though perhaps not probable, that some of this thick sedimentary series may be of later age than Lower Triassic.

WOODSIDE SHALE.

The Woodside shale, which immediately overlies the Phosphoria formation, takes its name from the Park City mining district, Utah. It is composed mainly of yellow and olive drab, platy, calcareous, and sandy shale which contains thin beds of gray dense limestones that weather brown or purplish. The limestones are few and relatively far apart in the lower part of the section but are more numerous and thicker bedded near the top. Some of the limestones are crowded with pelecypod shells, principally *Myalina*. In Utah and near Paris, Idaho, some of the beds of the Woodside shale are colored red. In most of the southeastern Idaho region the formation is characterized by the yellowish or olive-drab tints above noted. Near the base, however, in the Fort Hall Indian Reservation, the beds have a distinctive reddish-brown tint and are relatively sandy.

The base of the Woodside shale, which in regions previously studied has been rather sharply marked by a lithologic and faunal change, is not so clear in the region under discussion. The Paleozoic fauna locally found above the chert of the Rex member necessitates the location of the Triassic boundary above that fauna, which occurs in brownish-yellow sandy shales and limestones not easily distinguished lithologically from the Woodside, although the faunas of the Woodside and Rex, where well developed, are very different. In fact, this difference is so great as to suggest the probability of a stratigraphic break, though no angular unconformity has been observed.

The top of the Woodside shale is somewhat arbitrarily marked by the base of the *Meekoceras* zone, which represents the entry of the first fossil ammonites recognized in the faunas of these formations. The *Meekoceras* zone in this region is not as abundantly fossiliferous nor as lithologically distinct as in some of the districts in the vicinity of Georgetown or Montpelier previously studied. The upper limestones of the Woodside are relatively massive and grade lithologically into those of the overlying Thaynes.

The thickness of the Woodside shale in the Fort Hall Indian Reservation is somewhat less than in the Georgetown and Montpelier districts. In this region the Woodside is about 900 feet thick.

Topographically the Woodside shale is marked by relatively smooth slopes with few exposures except near the top, where the massive limestones form important ledges.

THAYNES GROUP.

General character.—The Thaynes limestone was named in the Park City mining district, Utah. In northeastern Utah and in the Georgetown and Montpelier districts of southeastern Idaho the Thaynes forms platy, calcareous shales like the Woodside, and brown weathering muddy limestones with a massive limestone at the top. In the last-named district the Thaynes limestone is about 2,000 feet thick. Toward the north and northwest the formation becomes thicker and shows a marked tendency to differentiate into several members that can be mapped as units. In the Fort Hall Indian Reservation these beds have a total thickness of about 3,650 feet, yet according to G. H. Girty[52] fossils similar to those of the upper limestone were found by C. L. Breger in shales which underlie the shale formerly called Ankareh in Montpelier Canyon, Montpelier quadrangle. As a result of subsequent work this shale is now regarded as part of the Thaynes. Thus the thicker series of beds in this district occupies the same stratigraphic interval as the Thaynes limestone farther southeast, and it has been found advisable to subdivide it into three formations, the Ross Fork limestone at the base, the Fort Hall formation, and the Portneuf limestone.

Ross Fork limestone.[53]—The Ross Fork limestone takes its name from Ross Fork Creek, in the upper waters of which this limestone is well exposed. The base of the Ross Fork limestone lies conformably upon the Woodside shale and is marked by the "*Meekoceras*

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[52] Personal communication.

[53] This limestone was previously described under the name Ross limestone. See Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, pp. 35–37, 1916.

beds" recognized by the Hayden Survey and referred to the Triassic and later referred by Hyatt and Smith [54] to the Lower Triassic.

The *Meekoceras* zone consists of gray to reddish-brown limestones about 50 feet thick, which contain numerous ammonites, the chambered shells of which appear on the weathered surface of the rock. In this region the fossils do not weather out so readily and the horizon is not so conspicuous as in the Georgetown district farther southeast. The *Tirolites* and *Columbites* zones, which have been recognized by Smith in the region of Paris, Idaho, 250 and 275 feet, respectively, above the *Meekoceras* zone,[55] have not been definitely recognized in the Fort Hall Indian Reservation, although there is some evidence of more than one ammonite horizon.

Above the *Meekoceras* zone for about 800 feet are massively bedded and thin-bedded gray to brown limestones, which contain large numbers of small brachiopods, chiefly *Pugnax* and terebratuloids, and pelecypods, *Myalina* and others, with intervening calcareous shales. The lithology of the shales and thinner-bedded limestones is much like that of the Woodside. The limestones have a sort of velvety appearance when weathered and are very fossiliferous. The presence of a small brachiopods in the massive limestones near the base is a convenient guide to the Ross Fork limestone, where the *Meekoceras* zone is not available.

The upper part of the Ross Fork limestone for about 500 feet consists of a dense calcareous gray to olive-greenish shale that weathers brown to yellow. These shales form conspicuous cliffs and are mainly nonfossiliferous.

The writer is indebted to G. H. Girty for the following faunal discussion of the Ross Fork limestone:

The fauna of the Ross Fork limestone consists chiefly of brachiopods, pelecypods, and cephalopods. The brachiopods and cephalopods are generally confined to zones which are narrow and possibly of small extent, but where found at all they are abundant. The brachiopods comprise a *Lingula*, a *Terebratula*, and a *Rhynchonella*, those terms being employed in a broad and general sense. The *Rhynchonella* closely resembles the Carboniferous species *Pugnax utah* and, as the Triassic occurs in the general region from which the type specimen was obtained, typical *Pugnax utah* may indeed be the Triassic form, as was suggested to me several years ago by Mr. Breger. A few specimens of a small *Discina* have also been collected.

The pelecypods consist mostly of pectinoids, of which there are many species. They probably include representatives of both the Pectinidae and Limidae, and they occur in some places in vast numbers, either alone or associated with other forms. Like most of these Triassic fossils, they belong to undescribed species, though one form can probably be referred to *Aviculipecten thaynesi-*

[54] Hyatt, Alpheus, and Smith, J. P., The Triassic cephalopod genera of America: U. S. Geol. Survey Prof. Paper 40, pp. 17 et seq., 1905.

[55] Smith, J. P., The distribution of Lower Triassic faunas: Jour. Geology, vol. 20, p. 17, 1912.

anus. Other types of pelecypods are much less common. The one most frequently found is similar to that described by White as *Volsella platynota*, but if my specimens really belong to White's species, I believe that it is a *Myalina*. A small alate shell, which may belong to *Bakewellia* or *Pteria*, has been found, and also forms which suggest the genera *Schizodus*, *Cardiomorpha*, and *Pleurophorus*. These last are so poorly preserved that their generic relations, even as based on external characters, are conjectural.

The cephalopods have been carefully investigated to the almost complete neglect of the rest of the Triassic fauna of this region. The Ross Fork limestone contains the most notable zone of the cephalopods—the *Meekoceras* zone. Nevertheless, the collections studied, which were not made with special reference to any one group of organisms, contain neither very numerous nor very complete specimens. The following species have been identified with more or less certainty: *Meekoceras mushbachanum*, *Meekoceras gracilitatis*, *Paranannites aspenensis*, *Ophiceras dieneri*, *Flemingites russelli*, *Clypites tenuis*.

Gastropods are so rare in the Ross Fork limestone that they might with little loss be neglected in a hasty survey of its fauna. One collection contains an abundance of small naticoid shells (*Natica lelia?*), but of much more interest is the occurrence in another collection of a species of *Bellerophon*. There can hardly be a doubt of the generic relationship of this form, which resembles the Pennsylvanian species *B. crassus*. The Bellerophontidae, though profusely developed in the Paleozoic and almost confined to that area, have been known in other parts of the world also to range up into the Mesozoic.

Fort Hall formation.—The Fort Hall formation is named from old Fort Hall, the site of which is in the valley of Lincoln Creek, a stream that is called on some maps Fort Hall Creek. The formation occupies a prominent ridge along the north side of this valley. The rocks lie conformably on the Ross Fork limestone. The dividing line is drawn on both lithologic and faunal grounds. There are four fairly well defined subdivisions.

(1) The base of the formation is a soft and somewhat sugary, yellow calcareous sandstone about 50 feet thick, which is sparingly fossiliferous and contains at one locality a bed of yellowish sandy limestone about 15 feet thick that carries plicated oyster-like pelecypods, terebratuloids, and other forms. This bed is overlain by white calcareous sandstone that weathers red or pink.

(2) Above these sandstones there is a gray or yellowish, siliceous dense limestone which contains large pectenoids and irregular cherty nodules and streaks that weather with a rough surface and project along the bedding planes. This limestone forms rough ledges and high points. The thickness of this series is estimated to be about 100 feet.

(3) At only two localities, secs. 36 and 26, T. 3 S., R. 37 E., there was observed above (2) a set of sandy and shaly gray limestones about 50 feet thick, including an oolitic bed 6 to 10 feet thick.

(4) The remainder of the section, estimated to be about 600 feet ·:kness, consists of yellow to grayish cherty and sandy limestones

in thin beds, which are represented chiefly by fairly smooth slopes strewn with yellow and reddish sandy and cherty float fragments.

Fossil collections have been made at a number of places in the Fort Hall formation. G. H. Girty contributes the following faunal discussion of the formation:

The Fort Hall formation might appropriately be called the *Aviculipecten idahoensis* zone, for it is particularly characterized by that species, which occurs in most of the collections and in many of them is very abundant. With *Aviculipecten idahoensis* are associated a few other types of pelecypods, among which a large *Bakewellia* or *Pteria* and two or three species of pectinoid shells are the most common. There is also a form resembling *Myalina* (possibly the *Volsella platynota* of the Ross Fork limestone but smaller and less abundant), and several types which are too poorly preserved to be identified, but in general expression suggest *Myacites*, *Schizodus*, and *Pleurophorus*. A small naticoid (*Natica lelia?*) is rather abundant in places, but otherwise gastropods are practically absent.

In contrast to the preceding formation, the Fort Hall does not contain any cephalopods nor, with the single exception noted below, any brachiopods. As regards the pelecypods, the pectinoid shells, except *Aviculipecten idahoensis*, are much less abundant in the Fort Hall formation, and some of the species of the Ross Fork limestone appear not to occur there at all. On the other hand, *Aviculipecten idahoensis* appears to be restricted to the Fort Hall formation.

One collection shows a remarkable and interesting variant of the Fort Hall fauna. It is distinguished by the absence of most of the pectinoids, even of *Aviculipecten idahoensis*, and by the abundance of terebratulas, of which there are four or five varieties or species. Of the pelecypods the most noteworthy are a large *Lima* (new species) and a sharply plicated oyster, beside which there are two species of *Myacites?*, a large *Bakewellia?*, and one or two other forms. The gastropods are represented by *Natica lelia* and by another species, possibly a *Pleurotomaria*.

PORTNEUF LIMESTONE.

The Portneuf limestone is named from Portneuf River, at the head of which the limestone is well exposed. The rock is a massive siliceous and cherty, gray to yellowish limestone. The chert occurs in rounded and elongated nodules and in streaks. Silicified fossils, including *Spiriferina* n. sp.?, *Terebratula semisimplex* and other terebratuloids, and *Myaphoria lineata?*, project from the weathered surfaces.

The formation is fairly resistant to erosion and forms low, broad ridges and sloping interfluvial areas. Its thickness is estimated at about 1,500 feet, although there is some uncertainty because of complexities of structure.

In the Lanes Creek, Freedom, and Montpelier quadrangles farther east a well-developed red bed member, which consists of interbedded red sandstones and shales and ranges in thickness from 200 to 1,000 feet, occurs in the midst of the Portneuf limestone. In the

Fort Hall Indian Reservation this was not recognized and if present is much less conspicuous than in the other regions named.

Numerous collections were made from this formation by G. H. Girty, who furnishes the following faunal discussion:

The Portneuf fauna is the most varied and interesting of the three Triassic faunas of the Fort Hall Reservation. Echinoid spines occur in a number of localities, but they are not plentiful. On the other hand, segments of the stems of *Pentacrinus* are often found in great abundance. In two localities Bryozoa are abundant—small branching types, which superficially resemble the Carboniferous genus *Batostomella*. Several new genera and species are indicated by thin sections. Brachiopods are abundant but confined to two families. The Portneuf contains the horizon of *Terebratula semisimplex*, and several other terebratuloid types, which are apparently undescribed, are also found in this formation. An undescribed species of *Spiriferina* is present in many of the collections, and there may be a second species.

Pelecypod types are numerous, though many of the specimens are poorly preserved. No species is more common in this fauna than one which was figured by Meek as *Myophoria lineata?*. The locality of Meek's specimen is given as Weber Canyon and the horizon as Jurassic. I can not but think that there is some mistake in the stratigraphic position of his material, which was said to be above the quarry rock, the quarry, I assume, being then as now, in the Nugget sandstone. As compared with their abundance in the two lower formations, pectens are scarce in the Portneuf. A large form with very coarse ribs is present in several collections, and there are other species, both large and small. A large *Pteria* or *Bakewellia* has been found at many localities; also a Myalina or *Mytilus*. *Leda* is present, and *Nucula*, together with types suggesting *Pinna, Myacites, Pleurophorus, Astarte, Cucullaea*, and other forms. One locality has furnished a few specimens of *Ostrea*, not only a plicated form similar to that of the Fort Hall formation but also a smooth type.

The scaphopods, too, are represented in this fauna by one or two species of *Dentalium*.

Gastropods are less abundant than pelecypods, the only common type being a small *Natica*, probably *N. lelia*. Several small species of *Pleurotomaria?* have been collected, and also shells suggesting the genera *Holopea, Nerita*, and *Macrocheilina*. The most interesting representative of this type, however, is a beautiful little species which apparently belongs to the Carboniferous genus *Schizostoma*, or at all events to the euomphaloid group.

Cephalopods are practically absent in this formation, as they are in the Fort Hall. One specimen only was obtained; it is apparently identical with *Pseudosageceras intermontanum*.

TIMOTHY SANDSTONE.[36]

The Timothy sandstone derives its name from Timothy Creek in the Lanes Creek and Freedom quadrangles, east of the Fort Hall Indian Reservation. The sandstone is well exposed in those quadrangles and is cut by the creek.

The beds that occupy this stratigraphic interval are somewhat sugary, yellowish to grayish sandstones in beds 1 to 3 inches thick. They weather down into smooth depressions between the more resist-

[36] Previously described as Ankareh sandstone. Mansfield, G. R., op. cit., p. 40.

ant formations on either hand. The sandstone is generally of uniform character and in some places weathers with a pinkish tinge. Its thickness is about 800 feet.

The base of the sandstone here seems to rest conformably upon the massive and siliceous Portneuf limestone, and the top appears to be overlain conformably by the Higham grit. In the Montpelier quadrangle, farther east, however, there is evidence that the Timothy sandstone is at least locally unconformable with both the underlying Portneuf limestone and the overlying Higham grit.

No fossils have yet been found in the Timothy sandstone. In the Fort Hall Indian Reservation it appears to be more intimately associated with the underlying Thaynes group than with succeeding formations. It is accordingly considered Lower Triassic. The unconformity at its base in the Montpelier quadrangle suggests, however, that the sandstone may prove to be of later age.

TRIASSIC (?) FORMATIONS.

AGE.

The great thickness of the formations assigned to the Lower Triassic—5,350 feet—the unconformity at the base of the Timothy sandstone in the Montpelier quadrangle to the east, and the unconformity at the base of the Higham grit suggest that this formation, together with the overlying Deadman limestone and Wood shale, may belong to the Middle or Upper Triassic or may be of later age than Triassic. The search for fossils in these formations has thus far been unrewarded. They are therefore doubtfully classified as Triassic.

HIGHAM GRIT.

The Higham grit is named from Higham Peak, in sec. 23, T. 3 S., R. 37 E., the highest summit in the northeast part of the reservation, which is composed of this rock. The grit is a coarse, white to pinkish, gritty or conglomeratic sandstone, which is distinct lithologically from other rocks of the region and forms prominent topographic features. It forms bold strike ridges that are marked by rough craggy ledges in many places, as shown in Plate II, *A*. The pebbles are all of quartzite, so far as observed. No material derived from immediately underlying formations has been observed in the Higham grit. The formation here appears to be conformable on the underlying Timothy sandstone, but the abrupt change in lithology and the apparently gradual transgression of underlying Lower Triassic formations farther east and southeast indicate an unconformity probably of considerable importance. The rocks are much fractured, a feature which causes them to weather in pinnacled and

castellated forms, and in many places they are slickensided, as a result of severe deformation. The thickness is about 500 feet.

The base of the Higham grit lies approximately 5,600 feet above the phosphate shales. Where an area is underlain by the Higham or later formations in normal position the phosphate lies too deep for recovery under present conditions.

DEADMAN LIMESTONE.

Stratigraphically above Higham grit and lying a short distance back of the crests of the ridges occupied by that formation lies a dense purplish-gray limestone of almost lithographic quality, which contains subordinate amounts of gray and greenish chert. This rock is called the Deadman limestone from Deadman Creek in the northeast part of T. 4 S., R. 38 E., near the headwaters of which it is exposed. The limestone is topographically resistant and in favorable places forms prominent ledges, as in sec. 25, T. 3 S., R. 37 E. Ordinarily, however, it is rendered inconspicuous by the proximity of the more resistant Higham grit. No fossils have been observed in this limestone, which is about 150 feet thick.

WOOD SHALE.

Next above the Deadman limestone in stratigraphic order there is a bright-red shale which weathers to a red soil. This rock is called the Wood shale, from Wood Creek, in T. 3 S., R. 38 E., which cuts across the shale and the overlying Nugget sandstone. It is less resistant than the adjacent rocks on both sides and occupies depressions or gullies. Locally pieces of gypsum lie here and there on the surface. Outcrops are few, but the shale may be traced by patches of bright-red soil. It is apparently 200 to 250 feet thick.

JURASSIC SYSTEM.

OCCURRENCE AND SUBDIVISION.

Jurassic rocks are exposed only in the northeastern part of the eastern mountainous region. They are divided into two formations, the Nugget sandstone, formerly regarded as Triassic or Jurassic, and the Twin Creek limestone.

NUGGET SANDSTONE.

As explained elsewhere (p. 44), the name "Nugget" is here restricted to the upper member or major part of the Nugget formation, as originally defined by Veatch. As thus restricted it is considered to be the equivalent of the White Cliff and Vermilion Cliff sand-

stones, from the upper part of which Gale[57] collected Jurassic fossils in the Uinta Mountain region of northwestern Colorado and northeastern Utah. Although the base of the formation in the Fort Hall Indian Reservation is apparently conformable upon the Wood shale, relations elsewhere suggest that an unconformity exists at this horizon. Two unconformities, one of which is probably extensive, occur, as previously noted, in rocks that lie between the Nugget and the fossiliferous rocks of the known Lower Triassic, and the stratigraphic unit which is believed to represent the Nugget within this interval has yielded only Jurassic fossils. For these reasons the Nugget sandstone is now referred to the Jurassic.

The Nugget sandstone succeeds the Wood shale, and consists in many places of brick-red, fine-textured sandstone in beds 1 to 6 inches thick, locally strongly cross-bedded, which form rounded hills that are strewn with angular, platy blocks weathered from the ledges. In other places the sandstone is somewhat firmer, coarser textured, quartzitic, and pinkish to whitish in color, weathering dark and forming slopes strewn with rough, blocky purplish talus. Markings that resemble footprints and other impressions were collected from these sandstones, but they proved to be too indistinct for identification. No other fossils have been found in the formation.

The stratigraphy of these sandstones has not been worked out, for the beds are involved in folds and faults, the details of which it was not practicable to determine, because the rocks are stratigraphically so far above the phosphate, which was the subject of investigation. The top of the sandstone is not exposed, or has not been recognized, for the overlying Twin Creek limestone cuts irregularly across the formation in a fault.

The thickness of the Nugget sandstone has not been measured, but it is estimated at not less than 1,500 feet.

TWIN CREEK LIMESTONE.

The detailed stratigraphy of the Twin Creek limestone, which overlies the Nugget sandstone, has not been worked out, but the formation may tentatively be divided into three parts:

1. Near the base a yellow calcareous sandstone with interbedded massive gray limestones crowded with oyster shells.

2. Thin-bedded, shaly whitish-gray and darker-colored limestone that weathers into chippy and splintery fragments. This is the part of the Twin Creek limestone that is exposed in the Montpelier and Georgetown regions farther southeast that have been previously studied.

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[57] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pp. 51, 52, 1910.

3. Yellow and grayish calcareous thin-bedded sandstone, more or less fossiliferous, together with some massive gray limestones.

The actual base and the top of the formation were not observed. Faults occur on both sides of the main area occupied by the Twin Creek in Tps. 2 and 3 S., R. 37 E., whereas in T. 3 S., R. 38 E., the formation is in large part overlapped by volcanic débris. In the Montpelier and Georgetown regions the Twin Creek limestone appears to be unconformable upon the Nugget sandstone.

A small area of massive limestones included in a fault block in sec. 31, T. 3 S., R. 38 E., is tentatively referred to the lower Twin Creek but may prove to be Triassic.

The fossils at several horizons indicate the marine character and Jurassic age of the formation.

The thickness of the Twin Creek limestone could not be measured in the Fort Hall Indian Reservation, but it appears to conform to the thickness observed in the regions described in the reports for 1909 and 1911 and is probably as great as 2,500 to 3,000 feet.[58]

TERTIARY SYSTEM.

SALT LAKE FORMATION (PLIOCENE?).

Beds of white marls or of dense yellowish to dove-colored limestones, together with generally light-colored conglomerates, composed of light or dark pebbles that have a white calcareous matrix, and some greenish clays and dark shales overlie unconformably the rocks of most of the older systems. Associated with these beds and interbedded with them are beds of white volcanic ash and greenish or yellow tuff or beds of partly waterworn volcanic débris. From the denser limestones in the SW. ¼ SW. ¼ sec. 1, T. 5 S., R. 36 E., fossils were collected and identified by W. H. Dall as internal casts of a gastropod which may be *Succinea* or *Lymnaea*, but which are not identifiable further. From one of the localities of marly limestone in the SW. ¼ NW. ¼ sec. 15, T. 5 S., R. 38 E., fossils were collected, which, according to the same authority, represent the internal casts of one or possibly two species of *Oreohelix* and one *Bifidaria*, both land shells and neither identifiable without more perfect material. The presence of *Oreohelix* suggests Pliocene age rather than early Tertiary.

From a locality in the SW. ¼ SW. ¼ sec. 23, T. 7 S., R. 33 E., where carbonaceous shales were exposed in an old coal prospect, plant remains were collected. These fossils were examined by F. H.

[58] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 480–481, 1910. Richards, R. W., and Mansfield, G. R., Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, p. 82, 1914.

Knowlton and proved to be fragments of stems and bark not determinable.

The fossils thus far found are not of sufficiently determinative value to establish definitely the age of these deposits. Lithologically and topographically the beds resemble those that were examined in the Montpelier and Georgetown districts and that have been described in a previous report.[59] Topographically also they are generally distinct from the alluvium that forms the bottom lands, and at many places they are sharply demarked from them by steep slopes. In Bulletin 470 they are referred tentatively to the Salt Lake group of Hayden[60] and Peale.[61] The same correlation is tentatively made here, and the beds are called the Salt Lake formation. It should be noted, however, that these beds have lithologic resemblances to the Payette and Idaho formations of the Boise district. The Payette formation was first considered Miocene but later referred by Knowlton to the Eocene. The Idaho formation is Pliocene.[62]

In three places—the SW. ¼ sec. 1, T. 5 S., R. 36 E.; the SE. ¼ sec. 21, T. 4 S., R. 37 E.; and the NE. ¼ sec. 3, T. 4 S., R. 37 E.—red conglomerates occupy small areas. They resemble lithologically the Eocene conglomerates in the southern part of the Montpelier quadrangle. In the SW. ¼ sec. 1, T. 5 S., R. 36 E., the red conglomerate is steeply inclined and seems to grade conformably into the lighter-colored conglomerate series. The evidence at present is not sufficient to differentiate the red conglomerate from the others.

The Tertiary beds cover many of the lower hills and form broad, gently sloping benches that descend from the higher hills and occupy much of the broader valley country. In some places, as in T. 5 S., R. 38 E., these lower hills and bench lands are strewn with boulders, locally of great size, which consist of white quartzite and the older limestones. In other places, as in sec. 36, T. 4 S., R. 36 E., the light-colored conglomerate consists almost entirely of small fragments of Triassic shaly limestone.

The thickness of the Salt Lake formation has not been determined. On some of the higher slopes it is doubtless comparatively thin; at lower elevations it may amount to several hundred feet.

UNDIFFERENTIATED TERTIARY AND QUATERNARY ROCKS.

Associated with the bench lands are some great alluvial fans, as in the west side of Tps. 5 and 6 S., R. 38 E., and east of the south fork

[59] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, p. 395, 1911. See also U. S. Geol. Survey Bull. 430, pp. 481–482, 1910, and Bull. 577, p. 33, 1914.

[60] Hayden, F. V., U. S. Geol. and Geog. Survey Terr. Fifth Ann. Rept., for 1871, pp. 154–155, 1872.

[61] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, pp. 588, 640, 1879.

[62] Lindgren, Waldemar, U. S. Geol Survey Geol. Atlas, Nampa folio (No. 103), 1904.

of Ross Fork Creek in Tps. 5 and 6 S., R. 36 E. These fans appear to bear the same relation to the higher hills as do the bench lands. They were doubtless deposited in the Putnam cycle of erosion when, as stated under the heading "Physiographic development," the bench lands were formed by the erosion of the weak Tertiary deposits. The erosional processes necessarily included a certain amount of aggradation by which materials of Tertiary age were rearranged and redeposited on lower slopes and in valleys. It has not been practicable in the mapping to differentiate between these rearranged light-colored materials and the Tertiary deposits, which they closely resemble. Areas in which Tertiary beds have been clearly differentiated have been mapped as the Salt Lake formation. Other areas which are underlain largely by Tertiary rocks but which include some of the redeposited materials are mapped as Tertiary and Quaternary. These deposits, together with the Salt Lake formation, underlie half or more than half of the surface of the reservation.

QUATERNARY SYSTEM.

SUBDIVISIONS.

Aside from the undifferentiated Quaternary deposits just mentioned three groups of Quaternary sediments have been identified and mapped, namely, older and recent alluvium and travertine.

OLDER ALLUVIUM.

A fairly sharp line of demarkation separates the older alluvium from the bench lands. A steep erosion slope truncates the lower ends of the benches in many places, whereas in others the lower ends of the benches form projecting fingers between which lie alluvial bottom lands. The erosion period that is represented by these steeper slopes apparently corresponds to the Gibson cycle and the surface underlain by the older alluvium constitutes the Gibson terrace. The older alluvium thus forms a broad plain 80 or more square miles in area in the northwest part of the reservation. The plain is generally marked by a very level surface with whitish soil and small pebbles. The pebbles, as exposed in the bluffs where crossed by the south line of T. 3 S., R. 34 E., consist of quartzite, quartz, chert, and igneous rocks, but there are few or none of limestone. The pebbles are subovoid to round and some of them are as much as 2½ inches in diameter. Many of them have calcareous coatings. On the Ross Fork road about 2 miles north of Fort Hall Agency the pebbles are cemented into a conglomerate. In some places boulders 1 foot or more in diameter are found on the surface.

Fossils were collected from the top of the bluff that overlooks Portneuf River in the SE. ¼ SE. ¼ sec. 9, T. 6 S., R. 32 E. The bluff

here ranges from 25 to 50 feet in height. The fossils were weathered out on the surface of a coarse argillaceous sand 15 feet thick that forms the top of the bluff at this place. Below this sand down to the level of the Snake River flood plain is a fine white soil. The fossils were submitted to W. H. Dall, who reports that they are probably not older than late Pleistocene, as they are all of living species, including *Sphaerium striatinum* Lamarck, *Carinifex newberryi* Binney, and *Fluminicola nuttalliana* Lea.

North of Ross Fork Creek the surface of the older alluvium is covered for a considerable area with dark volcanic sand that forms low dunes in some places, as in the southwestern part of T. 4 S., R. 34 E.

RECENT ALLUVIUM.

Recent alluvial deposits form the present flood plain of Snake River (the Fort Hall bottoms) and the flood plains of the lower courses of its larger affluents in this region, including Portneuf River, Bannock Creek, and others. The recent alluvium is associated with the latest or Spring Creek erosion cycle. It is usually separated from the older alluvium of the Gibson terrace by steep bluffs. The recent alluvium is composed of material similar to that of the older alluvium, except that, so far as observed, the sand cover is absent.

TRAVERTINE.

Deposits of travertine occupy most of the SW. ¼ sec. 33, T. 4 S., R. 38 E., and the SE. ¼ SE. ¼ sec. 28 of the same township. There are other smaller areas in T. 4 S., R. 35 E., which are associated with and apparently overlie the basalt. These deposits appear on the surface in thin broken fragments, and are in a number of places serviceable as indicators of the proximity of basalt. The larger areas first mentioned are associated with active springs, and it is probable that in some of them, as in sec. 28, T. 4 S., R. 38 E., deposition is still in progress. The deposits associated with basalt may be the result of leaching and redeposition of calcareous material from overlying soils.

IGNEOUS ROCKS.

Igneous rocks occupy large areas in the reservation and are prominent topographically. Their extent is probably considerably greater than their outcrop, for they are interbedded with or intruded into the Tertiary and Quaternary deposits and are largely concealed by them in many places. For example, there is little doubt that the low hills which occupy the west part of T. 4 S., R. 35 E., northeast of Fort Hall Agency, are mainly basaltic, although the actual outcroppings of basalt are scattered rather than continuous.

The several types of rock that are represented range in chemical and mineral composition from basalt to rhyolite. In weathering

also the igneous rocks present a corresponding variety of appearance. Thin sections have been made of the principal types, and these have been examined by E. S. Larsen, to whom the writer is indebted for the following identifications and descriptions:

Igneous rocks in the Fort Hall Indian Reservation.

Field No. of specimen.	Locality.	Name.	Petrographic notes.
C-37	NW. ¼ NW. ¼ sec. 30, T. 3 S., R. 36 E.	Augite-quartz latite.	Contains a few phenocrysts of plagioclase, augite, and iron ore in a fine groundmass, in part granophyric, in part spherulitic. Not far from a rhyolite.
C-31	SW. ¼ SW. ¼ sec. 21, T. 3 S., R. 36 E.	Rhyolite	Glass.
C-24	SE. ¼ NW. ¼ sec. 31, T. 4 S., R. 36 E.	Olivine basalt	Contains abundant laths of plagioclase, a less amount of olivine, considerable interstitial augite, and a little glass. Apatite and iron ore are also present. The plagioclase is calcic labradorite. The olivine is partly altered to iddingsite.
Mt. 165a	SW. ¼ SW. ¼ sec. 7, T. 2 S., R. 38 E.	Rhyolite	A thin section shows a few crystals of orthoclase and plagioclase in a groundmass which is largely glass with incipient crystallization. Porous streaks are more coarsely crystalline and carry tridymite.
Mt. 163	SE. ¼ SW. ¼ sec. 13, T. 3 S., R. 38 E.	Olivine basalt	A fine-grained rock made up of abundant laths of labradorite feldspar, considerable augite, tiny crystals of olivine, and grains of black iron ore. There is much brownish interstitial glass.
Mt. 97	SW. ¼ SE. ¼ sec. 23, T. 6 S., R. 33 E.	Augite-quartz latite.	Contains crystals of quartz, andesine feldspar, and augite in a granophyric to spherulitic groundmass.
M-306a	NW. ¼ SE. ¼ sec. 21, T. 5 S., R. 35 E.	Pyroxene andesite	Contains abundant phenocrysts of labradorite, some of pale-green augite, and many of an altered iron-stained pyroxene. The groundmass carries, among other materials, iron ore, plagioclase, and an altered mafic mineral. The rock is much altered, and secondary carbonate, chlorite, serpentine, sericite, and other secondary minerals are abundant.
M-202	SW. ¼ NE. ¼ sec. 22, T. 3 S., R. 37 E.	Hornblende andesite	Contains phenocrysts of pale-green hornblende and a few of plagioclase in a very fine grained groundmass made up of imperfectly developed laths of plagioclase, grains of augite and magnetite, and considerable undetermined material, which probably contains both quartz and orthoclase. It carries inclusions of sandstone.
M-194	Sec. 17, T. 3 S., R. 38 E.	Hornblende-pyroxene andesite.	The specimen is taken from a fragment included in andesitic tuff. A thin section of the rock contains phenocrysts of sodic labradorite, brown hornblende, partly resorbed, abundant augite, and hypersthene. The groundmass makes up somewhat less than half the rock, is microgranular to granophyric, and is made up of quartz, orthoclase, plagioclase, magnetite, and apatite.
M-192a	SW. ¼ SE. ¼ sec. 18, T. 3 S., R. 38 E.	Nepheline basalt	A very fresh, highly basic rock. The phenocrysts, which are nearly equal in amount to the groundmass, are chiefly olivine together with some augite and biotite. The groundmass is fine textured and is largely augite with interstitial material, which has an index of refraction about equal to that of Canada balsam, is weakly birefracting, and may be nepheline. There is a little apatite and iron ore.
M-44	NW. ¼ SW. ¼ sec. 22, T. 7 S., R. 33 E.	Olivine basalt	Contains abundant crystals of calcic labradorite and considerable olivine and augite in a clouded groundmass, which is largely composed of augite in fernlike or irregular skeleton crystals. There is probably a little glass.

The basalts all carry olivine and are in general relatively fresh and scoriaceous. They are well developed in the Bannock Valley region, in Tps. 3 and 4 S., R. 35 E., and in the canyon of Blackfoot River in the northeastern part of T. 3 S., R. 38 E. Specimen M–192a, which represents a single isolated locality, is especially noteworthy because of its content of nepheline. Nepheline basalts are relatively rare in the United States, being known at only a few widely separated localities in Montana, New Mexico, and Texas. The nearest of these localities to the Fort Hall Reservation is Lloyd, in the Bearpaw Mountains of Montana, about 400 miles away. A more extended description of this rock has been given elsewhere.[63]

The andesites are most abundant in the southeastern part of T. 3 S., R. 38 E., and form the chief component of a large area of tuff in the same township. Several small andesitic dikes have been recognized. Specimen 306a represents a much altered rock, the field relations of which were not determined. It has not been differentiated in the mapping from neighboring basalts.

The augite-quartz latites are extensively developed in T. 6 S., R. 33 E., and T. 3 S., R. 36 E., where they form prominent hills. They appear to represent, in part at least, the latest phase of volcanic activity in the region, as they include the rock of the little cone in sec. 30, T. 3 S., R. 36 E. (See Pl. IV.) The volcanic sand which covers so much of the lava and alluvial areas in the northwest part of the reservation is apparently composed largely of the glassy form of this rock.

The rhyolites are well distributed from the Bannock Valley region toward the northeast along the lower hills. They are particularly well developed in Tps. 7 and 8 S., R. 32 E., where they form massive ledges. As a rule they are more or less crystalline, but in some places they are glassy. The rhyolites and augite-quartz latites are grouped together in the mapping. They were not distinguished in the field.

Several dikes occur in different parts of the reservation. These dikes are of acidic and basic or of intermediate composition. The most conspicuous dike forms the great rhyolite hill which runs northwest from sec. 18, T. 8 S., R. 33 E., into the adjacent township.

Beds of volcanic ash and of more or less water-worn volcanic débris occur in many places, more or less closely associated with the lavas. In T. 3 S., R. 38 E., there is a considerable area of andesitic tuff. The volcanic sand above mentioned is the most recent volcanic feature. It overspreads much of the Gibson terrace but has not yet been recognized on the Fort Hall bottoms.

[63] Mansfield, G. R., and Larsen, E. S., Nepheline basalt in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 5, pp. 463–468, 1915.

The relative ages of the igneous rocks have not been worked out in detail, but there appear to have been at least four epochs of volcanic activity. An earlier basic or intermediate epoch, which was followed by an acidic epoch, is shown by included basic fragments in the great rhyolite dike mentioned above and by the fact that the andesitic tuff of T. 3 S., R. 38 E., is in places overlain by rhyolite. On the other hand, rhyolite is in several places overlain by basalt, as in the northwest corner of T. 8 S., R. 33 E., and in sec. 18, T. 2 S., R. 38 E. Finally both rhyolitic and basaltic areas are overspread in some places by the dark volcanic sand above mentioned.

There is some doubt about the identity of the basalts that are interpreted as belonging to the later series. The earlier basic series is known only from fragments in the rhyolite and in beds of volcanic débris that are overlain by rhyolite. These basalts may really be andesitic and related to the andesites that are overlain elsewhere by rhyolite.

There were several outpourings of basalt, as is shown by the successive flows that are exposed in the canyon of Blackfoot River. All the basalts mapped have been tentatively grouped in a single series. Some of the quartz latites are younger than the rhyolites, as shown by the dark volcanic sand. There are, too, some later acidic intrusives, which cut the basalt in secs. 15 and 21, T. 7 S., R. 33 E. These intrusives may be latites rather than rhyolites and may be contemporaneous with or earlier than the volcanic sand.

The andesites appear to be the oldest members of the volcanic series, for in sec. 31, T. 2 S., R. 38 E., the andesitic tuff is overlain by rhyolite and also by white and yellow Tertiary and Quaternary conglomerates. It is not clear that they underlie the Tertiary and Quaternary rocks altogether. They are more probably intercalated with those rocks and, like the rhyolites and basalts elsewhere in the reservation, are contemporaneous with parts of those deposits.

The basalts appear to antedate the Gibson cycle, for pebbles of basalt occur in the gravels of the Gibson terrace, and large boulders of basalt lie here and there on its surface. According to the fossil determinations suggested above, the Gibson terrace is probably late Pleistocene. Thus the basalts and earlier solidified lavas probably range in age from Pliocene to early Pleistocene. The hardened lavas of the Snake River region have been in general assigned to the Pliocene or Pleistocene, whereas those of the Columbia River are older.[64] Unless the Tertiary deposits of the Fort Hall Reservation are considerably older than is now thought probable, most of the lavas of the reservation would not be older than the Plio-

[64] Russell, I. C., Geology and water resources of the Snake River plains of Idaho: U. S. Geol. Survey Bull. 199, 1902.

cene. The basalts of the Blackfoot Canyon may possibly belong to an older series, yet their relative freshness and general similarity to the other basalts of the reservation appear to be unfavorable to this view.

STRUCTURE.

The geologic structure of the reservation is complex and involves both folding and faulting. There has been more than one epoch of deformation. The extensive cover of Tertiary and later deposits, which together with much solidified lava conceals half to two-thirds of the older rock structures, makes their interpretation difficult. A number of structure sections are shown on the map (Pl. III). In some places the details of structure are so numerous and so small that they could not be worked out under the existing conditions. The more important structural features of the eastern part of the reservation are described in the accounts of individual townships (pp. 71–104.)

FOLDING.

The Paleozoic and Mesozoic rocks have all been folded to a greater or less degree, but many of the folds have been so faulted that they lack continuity. This is true of all the larger folds and of many of the smaller. The largest and most conspicuous fold is shown in part in the northeastern portion of the reservation. The southwest limb of a syncline enters sec. 13, T. 4 S., R. 38 E., and continues northwest nearly to Blackfoot River, where it passes under cover. This syncline is inclined toward the northeast and the southwest limb is overturned in that direction. The central portions and the east limb of this fold are concealed by igneous rocks, and later sediments, and the west limb is cut by several faults.

Similar synclines, or perhaps parts of a single syncline that trends northwestward, underlie the northeastern part of T. 5 S., R. 38 E. These synclines are largely concealed, but they are important because they contain phosphate beds at available depths.

Another similar phosphate-bearing syncline, which is interrupted by minor folds and broken by faults, occupies the southwest corner of T. 4 S., R. 38 E.

An anticline in the northwestern part of T. 4 S., R. 37 E., which also involves the phosphate, is noteworthy because its axis trends northeastward at about right angles to the trend of the other folds mentioned. Numerous faults are associated with this anticline, especially in the region of the northeast tip.

In the region of North and South Putnam mountains, in Tps. 5 and 6 S., R. 37 E., the Cambrian rocks have been folded in different ways, but the stratigraphy and structure of these rocks have not been worked out.

In the northeast corner of T. 5 S., R. 36 E., and northwestward into the adjacent township there is an anticline of Upper Cambrian limestone which is flanked by Ordovician quartzite. This fold is overturned toward the southwest, a remarkable feature, for in most places in the reservation and in the Montpelier and Georgetown districts farther southeast the inclination of the folds is toward the northeast.

In T. 9 S., Rs. 32 and 33 E., and T. 8 S., R. 33 E., there are various folds in the Paleozoic rocks. In general the rocks trend northerly and dip easterly. The stratigraphy and structure of these rocks have not been worked out in detail. Faults cut the folds at several places.

FAULTING.

Faulting played a conspicuous part in the geologic structure of the region. A detailed discussion of the numerous faults in the eastern part of the reservation is given in the descriptions of the individual townships involved. One fault, or group of faults, however, merits special description.

PUTNAM OVERTHRUST.

The southern half of T. 5 S., R. 37 E., is occupied by the high rocky ridges and hills adjacent to North Putnam Mountain. These hills are largely composed of Cambrian quartzite and other Cambrian and Ordovician rocks. At a number of places, notably North Putnam Mountain and the ridges to the east, the capping rock is the dense white vitreous Swan Peak quartzite of Ordovician age. This rock appears to arch gently up over the mountain from northwest to southeast, but it has been eroded and is now separated into large and small detached areas. One of these detached areas forms the summit of North Putnam Mountain. The relations of the Ordovician quartzite to the underlying rocks may be explained as the result of either unconformity or of overthrust faulting. The latter view is regarded as more probably correct for the following reasons:

1. The Swan Peak quartzite, where it lies upon the Brigham quartzite, generally shows no conglomeratic phase near the base and carries no recognizable fragments of the underlying rocks from which it might supposedly be derived if unconformable. Minor exceptions to this statement have been observed in a few places in T. 5 S., R. 37 E., where a few pebbles of the underlying quartzite are included in the Swan Peak quartzite.

2. The Swan Peak quartzite in T. 5 S., R. 37 E., transgresses several other members of the Cambrian and Ordovician, including limestones and shales, but shows no signs of modification in composition

such as might be expected if originally laid down over rocks of these types.

3. Examination of other portions of the reservation shows that all the Paleozoic systems are represented, and that under normal structural conditions a full sequence of formations might be expected.

In T. 4 S., R. 36 E., a fault (Pl. III, section B–B′), which has a computed westerly dip of 20°, swings around the north and east base of the quartzite and limestone hills that extend southward from sec. 23 into T. 5 S., R. 36 E. It causes Cambrian and Ordovician limestones and quartzites to lie against the Ross Fork limestone of the Thaynes group, which comes to the surface through the Tertiary conglomerate in several ledges about half a mile to the east of the base of the hill. Although the thicknesses of many of the intervening formations are not known, it is clear that this fault produces a break of considerable magnitude which is measured probably by thousands of feet.

In the northeastern part of T. 5 S., R. 36 E., the Swan Peak quartzite swings across Ross Fork Creek in the tip of an overturned anticline, which causes the underlying Cambrian and Ordovician limestones to be exposed in the valley of that creek and along the west flank of the range of hills to the north. Apparently this block of limestones and quartzites is continuous with the block of Swan Peak quartzite south of the creek, so that in some way the thrust faults of T. 4 S., R. 36 E., and T. 5 S., R. 37 E., are connected. The place and mode of connection, however, are concealed by the Tertiary and Quaternary deposits. The two faults combined, as suggested on the map, may appropriately be called the Putnam overthrust from North Putnam Mountain, the most conspicuous portion of the upper fault block.

East of the fault in T. 4 S., R. 36 E., is another fault which approaches it within half a mile at the nearest point and then recedes north and south. This fault has a computed westerly dip of 33°, but the obliqueness of structure section B–B′ (Pl. III) reduces it to 25°. This fault lies between the Triassic area on the west and Cambrian and Ordovician rocks on the east of the same series as those that comprise the quartzite and limestone hills to the west. The question is raised whether this fault may be a continuation of the Putnam overthrust to the west or a separate fault perhaps subsidiary to it. If the second view is accepted, a part of the underlying Triassic block appears to have been thrust forward over the next block of the older rocks to the east, or else a portion of Triassic rocks from a higher group of strata, now elsewhere removed by erosion, has been underthrust between the two Cambrian and Ordovician blocks. If this fault is a continuation of the fault to the west, the

fault plane has not only been folded into an anticline but also inclined northeastward. It may be remarked in this connection that in T. 5 S., R. 37 E., the Putnam overthrust has been arched into an anticline and eroded but has not been overturned. In the Bannock overthrust,[65] 30 to 40 miles southeast, the fault plane has been both folded and overturned. There is then a precedent for this view as regards the Putnam overthrust, although it is perhaps wiser to consider this fault as a separate or a branch fault.

Another fault which is closely related to the Putnam overthrust and may be a branch of it lies along the boundary between T. 4 S., Rs. 36 and 37 E. This fault brings Cambrian and Ordovician limestones against Mississippian and Pennsylvanian rocks. This fault in turn is accompanied by subsidiary faults that form a zone of highly shattered rocks.

The dimensions of the Putnam thrust have not been determined. Its course within the reservation, exclusive of the more doubtful branches, extends 15 to 20 miles. To the northwest it is concealed by the Tertiary and Quaternary deposits. It is probably continued south of the reservation, but no examination of that region has yet been made. Plate I, *C*, shows a part of the region traversed by the Putnam overthrust and illustrates the character of some of the formations involved.

In secs. 14, 15, and 16, T. 5 S., R. 35 E., four faults are indicated that separate earlier from later Paleozoic rocks. These may be independent faults or separated parts of the same fault. They may also be related to the Putnam overthrust. The cover is extensive in this township, and the relations of these faults have not been worked out.

In the Bannock Valley region in Tps. 8 and 9 S., R. 33 E., and T. 9 S., R. 32 E., extensive faults separate the Cambrian and Ordovician from each other and from the Carboniferous rocks. (See Pl. III, section A–A'.) Along the southwest border of T. 8 S., R. 33 E., Cambrian and Ordovician limestones lie against the upper Mississippian Brazer limestone, and across the valley to the east similar Cambrian and Ordovician limestones with some Swan Peak quartzite lie against the lower Mississippian Madison limestone. In the southwestern part of T. 9 S., R. 32 E., Cambrian and Ordovician limestones with Swan Peak quartzite on the west lie against Pennsylvanian and older rocks on the east. It seems probable that these faults, which produce such similar effects, may be closely related or perhaps even connected beneath cover. The fault relations in the older rocks of Bannock Valley, T. 5 S., R. 35 E., and in the Putnam

[65] Richards, R. W., and Mansfield, G. R., The Bannock overthrust: Jour. Geology, vol. 20, p. 705, 1912.

overthrust are very similar, so that it is probable that they all are the result of the same deformative movements.

OTHER FAULTS.

In T. 7 S., Rs. 32 and 33 E., the rhyolites and basalts are normally faulted at several places and in T. 5 S., R. 35 E., the rhyolites have been similarly faulted. In T. 7 S., R. 33 E., the lavas on opposite sides of Bannock Valley are tilted away from each other with cliffs facing the valley. There is, therefore, some probability that this portion of Bannock Valley is in part of structural origin. Similarly the fault extending northwest from sec. 34, T. 7 S., R. 32 E., appears to have determined the location of the valley that coincides with it.

The general structural relations outlined above, together with additional details, are shown in the geologic structure sections that accompany the maps of individual townships (Pls. V to X) and in Plate III.

EPOCHS OF DEFORMATION.

Early epochs of deformation are recorded in the unconformities previously noted.

The youngest rock of the older group involved in folding and faulting is the Twin Creek limestone. The Tertiary and Quaternary deposits lie unconformably on these older rocks. The time interval between these formations is long—Jurassic to Pliocene(?). Within this interval several deformative epochs have been recorded in different parts of the western United States, and definite correlation of the deformative movements in the Fort Hall Indian Reservation with one or more of these can not be made without more complete data. There is, however, direct evidence of at least three deformative movements in the rocks of this region:

(1) The major deformation, which produced the main folds and the Putnam overthrust together with the other thrusts noted above, probably took place in the interval between the Cretaceous and Eocene. In a previous paper[66] it was suggested that the Bannock overthrust was produced during the interval of deformation and erosion between the Adaville and Evanston formations of southwestern Wyoming, discussed by Veatch.[67] A similar correlation might be tentatively made for this great deformative epoch in the Fort Hall Indian Reservation. To this epoch may probably be assigned the overturning of the synclines in the northeastern part of the reservation and the development of the sharp folds and strike

[66] Richards, R. W., and Mansfield, G. R., The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, p. 704, 1912.

[67] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, p. 76, 1907.

faults in the Nugget sandstone and underlying Triassic (?) formations of the same locality.

(2) The plane of the Putnam overthrust has been deformed and eroded on Mount Putnam, and if the eastern fault in T. 4 S., R. 36 E., is considered a part of that thrust it has even been overturned. These movements were doubtless subsequent to the main deformative period and may have occurred in early or middle Tertiary time. There has been, however, some deformation of the beds regarded as probably Pliocene (Salt Lake formation) in this region, for limestones and conglomerates in secs. 1 and 2, T. 5 S., R. 36 E., have dips ranging from 35° to nearly vertical. In other localities also, as in secs. 10 to 15, T. 8 S., R. 33 E., beds of the Salt Lake formation have dips of 50°–75°. The deformation which produced these steep dips must have taken place late in Pliocene time or at the close of that epoch. Crustal movements appear to have been rather general at that time and probably the deformation of the thrust planes mentioned above may have occurred then and renewed movements may have taken place in the earlier folds and faults.

(3) The basalts, which overlie the Salt Lake formation and rhyolites in T. 7 S., R. 32 and 33 E., are normally faulted at several places. The rhyolite is also faulted in T. 5 S., R. 35 E. The fault scarps may be recognized in several places and are still comparatively fresh, as in the southwest corner of T. 7 S., R. 33 E. These faults are probably to be referred to the close of early Pleistocene time, for the basalts themselves are probably of post-Pliocene age. The faulting may have accompanied the uplift which inaugurated the Gibson erosional cycle, because in Bannock Valley the older alluvium which represents that cycle passes between the basaltic hills along the line that separates the basalts that dip eastward from those that dip westward.

GEOLOGIC HISTORY.

The earliest rock formation in the Fort Hall Indian Reservation is the Brigham quartzite, which according to Walcott is the overlapping shore deposit of Middle and Lower Cambrian time, along what is now the Wasatch Range, derived from the Uinta region. No fossils were observed in this formation in the reservation, but in the Liberty and Blacksmith Fork sections described by Walcott[68] annelid trails and trilobite tracks were found and in the upper part of the formation in the Liberty section characteristic Middle Cambrian fossils were found. The thickness of the deposit, which is 2,000 feet at the type locality near Brigham, Utah, together with its

[68] Walcott, C. D., Nomenclature of some Cambrian Cordilleran formations: Smithsonian Coll., vol. 53, pp. 9, 199, 1908.

locally cross-bedded and conglomeratic character indicate the long continuance of shallow-water conditions and the generally slow subsidence of the region with the advance of the Cambrian Sea. Barrell[69] has pointed out that thick deposits of coarse sediments are likely to be of nonmarine origin. Possibly a more detailed study of the Brigham quartzite will show that some of it may be of subaerial origin.

After its advance in Brigham time the sea held sway with some interruptions over the region of the reservation throughout Paleozoic and for part at least of Mesozoic time. The character of the sea, the position of the shores, the elevation of the adjacent lands, and the conditions of deposition changed from time to time as indicated by the changes in the lithology and fauna of the sediments. The occurrence of shales and sandstones in parts of the section indicate the admixture of relatively large amounts of detrital material from the land, due to such causes as elevation or silting up of the sea bottom or proximity to the mouths of great rivers. The occurrence of limestones, on the other hand, implies clearer seas, such as might be found in deeper waters at some distance from shore or in shallow water near some base-leveled land, where such materials as were carried from the land to the sea were largely in a state of solution. Changes in conditions of deposition are also accompanied by changes in the character of the fauna. Some types, such as pelecypods, usually frequent more muddy waters, whereas other types, such as corals, live best in clearer seas.

A notable reversion to shallow-water conditions, which was rather widespread, occurred in Ordovician time, when the Swan Peak quartzite was laid down. After the deposition of this formation there was a return to deeper-water conditions and limestones were deposited until the middle of the Pennsylvanian epoch, when sandstones and quartzites were again formed over wide areas. The evidence relating to Silurian and Devonian time is fragmentary, for the formations of those periods, though represented in a number of rather widely separated areas, are in many places not well developed, and their relations to the overlying and underlying rocks are not clear. However, in this region they are limestones, and so far as their relations with other rocks have been observed they appear to be conformable with the rest of the series. An unconformity between the Mississippian and Pennsylvanian has been identified by Blackwelder[70] in Weber Canyon, Utah, but this condition does not seem to have been general. After the sandstones of the middle Pennsylva-

[69] Barrell, Joseph, Some distinctions between marine and terrestrial conglomerates; Geol. Soc. America Bull., vol. 20, p. 620, 1909.

[70] Blackwelder, Eliot, New light on the geology of the Wasatch Mountains, Uta' Geol. Soc. America Bull., vol. 21, p. 530, 1910.

nian were deposited limestones were again formed for a time. Then came a most remarkable change.

In the Permian epoch there was more or less crustal disturbance throughout the North American continent, which resulted in the great Appalachian-Ouachita revolution in the East, and in different parts of the West in the interruption of marine deposition. In the region of the Fort Hall Indian Reservation and adjacent parts of southeastern Idaho, northwestern Wyoming, northeastern Utah, and southwestern Montana, there was marine deposition but under different conditions. The sea in these regions became smaller. A special fauna developed and a remarkable series of phosphate beds, phosphatic shales, and limestones were formed.

Although the Woodside shale of the Lower Triassic lies with apparent conformity upon the Phosphoria formation there is a marked lithologic and faunal change that indicates a corresponding difference in conditions of deposition and probable unconformity. The shales of the Woodside are highly calcareous, and many beds of limestone are included in the formation, especially near the top. Unlike the clear seas that must have prevailed during the deposition of the Rex chert member of the Phosphoria, the waters of the Woodside sea were to some extent roily, and the fauna was chiefly of pelecypods. These conditions lasted with some variations throughout the period of deposition of the Woodside and of the lower Thaynes. In the time of the middle and the upper Thaynes there was more or less alternation of shallower and deeper water together with the deposition of shaly and arenaceous beds in alternation with clearer limestones. The close of the Thaynes epoch was marked by deeper and clearer seas and the deposition of the heavy-bedded Portneuf limestone.

The change from the Portneuf limestone with its characteristic fauna to the overlying Timothy sandstone without a recognized fauna is well marked lithologically. The unconformity at the base of the Timothy in the Montpelier quadrangle indicates that at least locally the Thaynes group was subject to erosion and hence had been partly exposed before the Timothy was deposited. The change in conditions of deposition must also have been fairly marked, and it probably included a notable shallowing of the sea.

The coarse quartzitic débris, which forms the Higham grit, indicates another marked depositional change. The extent and uniformity of the grit in regions outside the reservation point to marine deposition as the most probable agent in its formation. The land probably stood higher with reference to the sea or the grades were st [illegible] at coarser material was furnished by the streams to the [illegible] preceding Triassic epochs. This change which appar[illegible]n unconformity, as indicated by conditions farther

east, was rather widespread. The succeeding limestone and red gypsiferous shale appear to indicate deposition in a portion of the sea that was more or less cut off from free communication with other portions. Evaporation was sufficient to render the waters unfit for marine life and to cause the deposition of minor amounts of gypsum but did not continue to the point of saturation for chlorides. The succeeding red beds of the Nugget sandstone by their color and also by the occurrence of ill-defined markings resembling footprints suggest nonmarine deposition, but the generally even bedding and the character of the cross-bedding, where shown, are not entirely favorable to such a supposition. These beds may be in part nonmarine.

In regions to the east some erosion appears to have intervened between the deposition of the Nugget sandstone and the Twin Creek limestone. In the Fort Hall Indian Reservation the boundaries of the two formations seem to have been largely determined by faulting. During the deposition of the Twin Creek limestone normal sea water with abundant marine life occupied at least the northeastern part of the reservation, and in the large arm of the sea which included this area a thick body of calcareous sediment accumulated under conditions that differed in the earlier and later parts of the epoch but that remained quite uniform through much of it, as shown by the peculiar shaly character of a large part of the rock.

The sea persisted through the greater part of Upper Jurassic time but was probably excluded by deformative movements at the end of the Jurassic. No Cretaceous sediments are present in the reservation, but in neighboring regions to the east nonmarine Lower Cretaceous (?) beds occur in great thickness and in such coarseness as to imply steep grades for streams.

The land masses from which the Paleozoic and Mesozoic rocks were derived lay chiefly to the east and southeast, for the sediments appear to become more siliceous and coarser in those directions, but the nature and extent of these lands is unknown.

The next important event recorded by the rocks of the region is the great deformation which produced the many folds and overthrust faults already described. In the absence of evidence to the contrary this event is placed in the interval between the Cretaceous and the Eocene, when many of the great structural features of the West were developed.

The record of Tertiary events in this district is not very complete. The reservation must have suffered some of the deformation, volcanism, erosion, and aggradation that were experienced by other parts of the western United States during Eocene and Miocene time, but if so the features to be assigned to these periods have not be differentiated. The Tertiary deposits represented have been

signed tentatively to the Pliocene. Previous to their deposition long-continued erosion had reduced the hills to subdued outlines and had excavated broad valleys in which by the topographic revival of the region the deposits of the Salt Lake formation were laid down. Faulting may also have played some part in the formation of the basins which received these sediments as suggested by the volcanic phenomena noted below. These deposits were so abundant that they covered practically all the lower elevations in the reservation and even overspread some of the higher hills. They were doubtless in large part composed of materials deposited by streams, but some of the beds—marls and shales—were deposited in bodies of water. Volcanic phenomena played an important part during this epoch, and much volcanic material in the form of beds of tuff and ash, together with intermediate or basic and acidic lava now solidified, is included in the deposits. Deformation again occurred in the later part of this epoch of aggradation and disturbed the position of the deposits. Doubtless, too, it revived to a certain extent the fold and fault structures of the older rocks and warped or folded the existing thrust planes. Probably about this time also occurred outflows of basalt that now cap Pliocene (?) hills in T. 7 S., Rs. 32 and 33 E., and form the broad hills of igneous rock in Tps. 3, 4, and 5 S., R. 35 E. Possibly, too, the basalt of Blackfoot River, which is partly overspread with wash of Pliocene material, may have been outpoured at this time. This deformation was probably synchronous with the general movements that marked the close of the Pliocene elsewhere in the North American continent.

During the earlier part of Pleistocene time the older rocks and the Salt Lake deposits seem to have been eroded into the late mature forms of the present topography associated with the Putnam cycle. There are no evidences of Pleistocene glaciation in the region of the Fort Hall Indian Reservation. There are, however, numerous great boulders of quartzite and limestone that are scattered irregularly about over the surface of the Salt Lake deposits that might at first sight be attributed to glacial action. These are regarded as weathered from the surrounding weaker conglomerate.

The later Pleistocene epoch was ushered in by changes, which permitted erosion of the early mature canyons and associated topography of the Gibson cycle as described elsewhere (p. 16). In the vicinity of Mount Putnam the canyons of this erosion cycle are cut to depths of about 1,500 feet, but in some of the lower hills the canyons are less than 1,000 feet in depth. Along the inner margins of the Gibson terrace the top of the terrace is separated from the tops of the adjoining benches by steep slopes 75 to 100 feet high. The flatter grades developed in the Gibson cycle suggest that the rejuvenation activity of that cycle may have been in part due to

more moist climatic conditions than those of the preceding cycle. There was doubtless also some broad upwarping of the region, for the normal faulting in the basaltic hills of T. 7 S., Rs. 32 and 33 E., appears to have preceded the development of the Gibson terrace in Bannock Valley. In the later part of this cycle probably occurred the latitic eruption, which covered so large an area in the northwestern part of the reservation with dark volcanic sand. It seems probable, too, that this cycle represents the part of the Pleistocene in which elsewhere glaciers were present and in which existed the great Pleistocene lakes of the Great Basin. The waters of Lake Bonneville, the largest of these lakes, for a time found outlet to Snake River by way of the Portneuf.

The recent or Spring Creek erosion cycle has been relatively short. Although broad flood plains have been developed during the cycle in the vicinity of Snake River and the lower courses of its larger affluents erosion has as yet made little headway in the hard rocks of the higher hills. The Snake River flood plain near the junction of Snake and Portneuf rivers, in T. 6 S., R. 32 E., stands about 75 feet below the Gibson terrace, but in the northwest corner of T. 4 S., R. 34 E., it is only 15 feet lower. In the valley of Ross Fork Creek and Bannock Creek the difference in elevation dies out upstream. Thus the grades of the flood plains developed in the Spring Creek cycle are steeper than those established in the Gibson cycle and cut across them at a faint angle. The cause of this difference in grade between the two sets of flood plains may be due in some measure to the introduction of a more arid climate than that of the Gibson cycle, for, if other conditions remain the same, rivers tend to develop steeper grades during a period of arid climate than during a period of moist climate. The introduction of the Spring Creek cycle may thus have been due partly to climatic and partly to deformational influences, but the relative proportion assignable to each influence has not been determined.

DESCRIPTIONS OF TOWNSHIPS.

As the examination of the Fort Hall Indian Reservation was made primarily for the purpose of studying the character and extent of its phosphate deposits, a more detailed description is given of those townships that are believed or known to contain phosphate. These townships are all in the eastern mountainous region.

T. 3 S., R. 36 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line R road runs through T. 3 S., R. 35 E., at a distance of 3 to 6 miles of T. 3 S., R. 36 E. The city of Blackfoot is 3 miles from the

west corner of the township. The site of the second old Fort Hall is near the center of sec. 24. From this point wagon roads run northwest to Blackfoot, southwest to Fort Hall, and southeast to Soda Springs.

GEOLOGY.

The main geologic features of the township are shown on the general map of the reservation (Pl. III). In the northeast corner of the township small areas of Nugget sandstone and Twin Creek limestone appear from beneath the Tertiary and Quaternary cover. No other formations of the older rocks are known to outcrop in this township, but in sec. 30, T. 3 S., R. 37 E., the Portneuf limestone of the Thaynes group occurs within a few hundred feet of the township line. These beds appear to strike southwest and doubtless enter the southeast corner of this township underneath the cover of later sediments.

The Tertiary and Quaternary deposits include a group of sediments with associated beds of volcanic débris, probably of Pliocene age (Salt Lake formation), with perhaps some reworked material of Quaternary age. They probably cover most of the township but are overlain in large part by a cloak of dark volcanic sand. Alluvial deposits of Quaternary age occupy the valley of Lincoln Creek, in which the site of old Fort Hall, now a farm, is located.

The igneous rocks include augite-quartz latite, near rhyolite in composition and not differentiated from it on the map, and basalt. The relations of the igneous rocks to each other have not been carefully worked out, but it seems probable that there have been several alternate outpourings of acidic and basic volcanic rocks in this township and that the latest of them were acidic, the site of the eruption being probably the little symmetrical cone in the NW. ¼ sec. 30 (Pl. IV, *B*). This cone is composed of dark, partly devitrified glass, that seems to grade near by into augite-quartz latite. It has no crater but is composed of sheets of lava with outward quaquaversal dip. The texture of the rock in the cone is different from that in the neighboring flat-lying sheets. In the cone the rock has a granular, spheroidal texture, the individual granules being about one-eighth inch in diameter, together with irregular cavities an inch or more in diameter and balls of similar dimensions that have radial structure. These features suggest that this was a center of eruption of viscous lava. The dark volcanic sand that overspreads a large part of this township and parts of adjacent townships is composed largely of material similar to that which constitutes this cone. It may have been the product of an explosion preceding the upwelling of the lava that now forms the cone. Plate IV, *A*, shows the latitic hills, with the little cone, and Plate IV, *B*, gives a nearer view of the cone.

A. VOLCANIC HILLS (AUGITE-QUARTZ LATITE) IN THE NW. ¼ SEC. 30, T. 3 S., R. 36 E., SURMOUNTED BY LITTLE CONE.

View from a point about 1½ miles south.

B. NEARER VIEW OF THE CONE SHOWN IN *A*.

On the summit has been placed a bench mark of the United States Geological Survey.

PHOSPHATE DEPOSITS.

Athough there is no known outcrop of the Phosphoria and associated formations within this township, it may be postulated from conditions in secs. 30 and 31, T. 3 S., R. 37 E., and sec. 2, T. 4 S., R. 36 E., that the phosphate shales enter this township beneath cover about 500 feet south of the northeast corner of sec. 36, trend in a convex curve toward the northwest, and leave the township in the vicinity of the southwest corner of sec. 36. The dip in the NW. ¼ NW. ¼ sec. 29, T. 3 S., R. 37 E., is 50° SE., and in the SW. ¼ SE. ¼ sec. 31, T. 3 S., R. 37 E., the dip is 25°.

On the basis of this postulated structure there would be a belt about 5,500 feet wide in secs. 25, 26, 35, and 36 that would contain phosphate deposits within a probable depth of 5,000 feet. In view, however, of the complicated structure, especially faulting in the adjoining townships, and the extent of cover, it is not safe to assume the actual presence of the phosphate, and hence no estimate of the character and tonnage of the rock is attempted.

OTHER MINERAL DEPOSITS.

No mineral deposits of value have been recognized in the township. In the NE. ¼ SW. ¼ sec. 20 a buff fine-grained tuff has been opened, perhaps in a search for building material. It is, however, too soft to be of use for this purpose. In a locality near by the rhyolite has been opened, probably also in search of building material.

SOILS.

The alluvial deposits in Lincoln Creek can be irrigated and are partly cultivated in farms. The soils from the Tertiary and Quaternary formations, which occupy considerably dissected sloping benches, are in part available for dry farms. The sand-covered area has a soil too loose and incoherent for agriculture, but it may be utilized in grazing.

T. 4 S., R. 36 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line Railroad runs 6 or 7 miles west of T. 4 S., R. 36 E. Fort Hall and Blackfoot are about equidistant from the center of the township, and there are well-traveled roads to each place. The road to Blackfoot is heavy because of the coarse and deep sand. A road to the Blackfoot Dam, Soda Springs, and other places, passes east along Ross Fork Creek in the southwest part of the township.

GEOLOGY.

STRATIGRAPHY.

The sedimentary rocks of the township range in age from Cambrian to Quaternary. The geologic features of this township are shown on the general map of the reservation (Pl. III). The oldest rocks recognized are cherty limestones of Cambrian and Ordovician age. They lie along the west flanks of the hills in the eastern part of the township and constitute much of the big hill in sec. 23 and vicinity. The east ridge which extends through secs. 24 and 13 is composed in part at least of rocks of these ages, but some of it may be Silurian or Devonian. The rocks of this ridge are sparingly fossiliferous and much broken, and it was not practicable to map the formations involved. The Swan Peak quartzite forms the crest of the ridge in secs. 26 and 35 and occurs in small detached areas elsewhere, mainly with synclinal structure. The Fish Haven dolomite overlies the Swan Peak quartzite along the east side of the ridge mentioned above and is probably the limestone that accompanies the quartzite on the west in sec. 14.

Fossils regarded by Edwin Kirk as probably of Devonian age, though possibly Madison, were found in the SW. ¼ NE. ¼ sec. 12. On the basis of these fossils the hills north of the main valley in the SE. ¼ sec. 12 are tentatively mapped as Devonian. Dark limestone much shattered and veined, along the east side of the ridge in sec. 13, may also prove to be Devonian but have not yet been recognized as such.

The high hill in the NW. ¼ sec. 18, T. 4 S., R. 37 E., about half a mile east of the township, carries Madison fossils, whereas the hill in the NW. ¼ sec. 6 of that township carries fossils of upper Mississippian (Brazer) age. The boundaries of these two formations have not been determined. At two localities in sec. 11 Carboniferous fossils of the Wells (Pennsylvanian) and upper Mississippian (?), respectively, have been found, but here again it has not been practicable to differentiate the formations. In the NE. ¼ NE. ¼ sec. 25 Wells limestone lies against Ordovician limestone, probably owing to faulting.

The Ross Fork limestone of the Thaynes group, without intervening lower formations, lies in close proximity to Ordovician limestones in the NW. ¼ sec. 23 and the SW. ¼ sec. 24. It outcrops also in the NW. ¼ sec. 2.

The Tertiary and Quaternary sediments form a cover that conceals much of the stratigraphy and structure of the township. The -y deposits occupy the broad flat in the valley of Ross Fork e southwestern part of the township.

Igneous rocks, both rhyolites and basalts, occur in some places in the township. The rhyolites occupy the northern and north-central part, but basalts in small exposures are more widespread throughout the western part of the township. A belt of acidic glass accompanies the rhyolite in sec. 3 and beds of light-colored volcanic ash are interbedded with the rhyolites and Salt Lake beds in secs. 10 and 11 (Pl. XI, *A*). The so-called rhyolites are not true rhyolites, but rather are augite-quartz latite, very near rhyolites in composition and not differentiated in the mapping. The basalt contains olivine. The relations of the igneous rocks to each other have not been definitely worked out. It seems probable, however, that there have been several epochs of volcanic activity accompanied by alternating eruptions of acidic and basic rocks. The latest eruptive rocks appear to have been acidic and to have produced the dark volcanic sand that overlies the northwest corner of the township and is discussed in the description of T. 3 S., R. 36 E.

STRUCTURE.

The geologic structure of the township is complex and involves both folding and faulting, but the influence of faulting is predominant. The general structural features of the township are shown in the geologic section (B–B′, Pl. III).

Folds.—So far as the evidence has been interpreted the structure is marked by many relatively small folds rather than by fewer large ones. The two main ridges from sec. 23 southward and from sec. 24 northward are synclinal and anticlinal respectively, but in the eastern ridge particularly the rocks are much brecciated and seamed with calcite.

Faults.—The most pronounced structural features are two faults, which, though largely concealed, leave no doubt as to their reality and produce noteworthy structural discordance. These faults are discussed on page 63. (See structure section B–B′, Pl. III.)

The shattered condition of the rocks along the east side of the crest of the ridge in sec. 13 is the basis of the fault there shown. The rocks are comminuted and veined in a remarkable manner, but the rocks concerned are all of the earlier Paleozoic series, so that the postulated fault did not produce any great displacement. It is regarded as a branch of the great fault that enters the northeast corner of sec. 13 and that separates the older Paleozoic rocks from the Carboniferous and later rocks on the east. The small faults in the SE. ¼ sec. 12 represent similar shatter zones.

In the northeast corner of sec. 25 the lower part of the Wells formation lies against the older Paleozoic rocks. The Tertiary cover conceals all but a small area of this formation in this part of

township. The nearest ledges southwest of the overthrust fault lie nearly a mile to the northwest, and these expose the Ross Fork limestone. The rocks are thrown into several small folds, but the trend of the axes is roughly parallel to the course of the fault, and if continued would be likely to bring these Triassic beds into proximity with the Wells. The branch fault in sec. 25 is drawn to indicate such a possibility.

In sec. 14 a transverse normal fault cuts the overthrust and produces an offset in the quartzite and underlying limestone. A small rhyolite dike occurs along this line in the SW. ¼ sec. 14, and farther northwest a large flow of rhyolite comes in along the same general course. The downthrow here is probably to the northeast, because the limestones in that direction appear to represent higher formations than the Swan Peak quartzite, which on the southwest of the fault is caught here and there in little synclines.

Covered area.—Nothing can be stated with certainty regarding the structure of the covered area, but two suggestions may be made. The presence of the Cambrian and Ordovician area on the east side of sec. 21 and of the hill of Swan Peak quartzite in the northeast corner of sec. 20 suggests the continuance of the overthrust fault from sec. 22 beneath the cover westerly or northwesterly perhaps as far as the township line. It seems probable that to the south of such a line the underlying rocks are of the older Paleozoic series.

To the north of that line it seems probable that the underlying rocks are of Triassic age, though perhaps some may be of Permian or older Carboniferous age, because of the occurrence here and there of Triassic float, probably weathered from Tertiary conglomerates but not much rounded, and of phosphate float apparently from similar sources. In the northwestern part of the township the sand and igneous rocks so effectually conceal the sediments beneath that there is no clue to the underlying structure.

PHOSPHATE DEPOSITS.

The occurrence of abundant Triassic float and of some phosphatic float in the covered areas, together with actual ledges of Triassic limestones of the Thaynes group, all make it very possible that some of the northern and eastern portions of the township are underlain by phosphate deposits. The sections and analyses of the phosphate beds in Tps. 4 and 5 S., R. 37 E., make it probable that the phosphate would be of high grade and in beds of workable thickness. The presence of great faults and of extensive cover makes hazardous, however, any attempt to estimate the areas underlain by these deposits or to estimate their tonnage.

OTHER MINERAL DEPOSITS.

In secs. 10 and 11 are extensive beds of white volcanic ash (Pl. XI, *A*) which consists largely of fragments of glass with some feldspar that have a maximum diameter of about 0.1 millimeter but are mostly fine enough to pass through a 100-mesh screen. This material might be suitable for some scouring preparations. No other mineral deposits of value were recognized.

SOILS.

The volcanic sand in the northwestern part of the township is too coarse and incoherent for agriculture. The Tertiary slopes could be used for grazing or dry farming. The alluvium in Ross Fork Valley can be irrigated and is partly utilized in farms.

T. 3 S., R. 37 E.

TRANSPORTATION FACILITIES.

The city of Blackfoot, on the Oregon Short Line Railroad, is about 9 miles almost due west from the northwest corner of T. 3 S., R. 37 E. The distance by road is 4 or 5 miles longer. Two roads, high level and low level, respectively, pass up the valleys of Cold Creek and Lincoln Creek. The eastern two-thirds of the township is hilly, and the valleys trend northwest. Bold ridges between the valleys impede travel across country to the northeast.

GEOLOGY.

STRATIGRAPHY.

The stratigraphic succession in this township ranges from Pennsylvanian to Quaternary, but the highest of the well-consolidated sediments is the Twin Creek limestone.

Only a small area of Carboniferous rocks is known to be present in the township, and their position is somewhat doubtful. They are tentatively considered Pennsylvanian. The Phosphoria formation, if present, is concealed beneath the Tertiary rocks of the valley of Lincoln Creek.

The Woodside shale is exposed in two areas in secs. 34 and 35.

The Thaynes group is represented in two belts in the southern and northeastern parts of the township, respectively. Both belts are more or less broken by faults. In the northeast belt only the Portneuf limestone is represented. There are several small areas bounded by faults in secs. 15 16, and 24.

The Timothy sandstone also occurs in two general belts which accompany the Thaynes and is likewise broken by faults. In sec. 10 the Timothy is brought in by small broken folds.

The Nugget sandstone occupies much of the northern half of the township, where it forms big rounded hills. The Higham grit is a conspicuous topographic feature both in Higham Peak and in the NE. ¼ sec. 3. The Deadman limestone and Wood shale are also well represented.

The Twin Creek limestone is confined to the northeast corner of the township, to scattered areas in the northwest, and to an area apparently bounded by faults in secs. 14, 15, 22, and 23.

The Tertiary deposits underlie the sloping benches in the west and south and also lie in patches on some of the higher hills. Some of these patches are indicated, but their boundaries were not carefully ascertained.

A small area of alluvium in the valley of Lincoln Creek enters the township from the west.

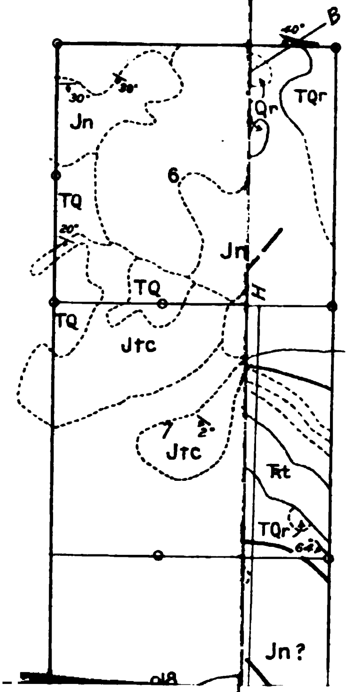
Igneous rocks, chiefly of the rhyolite group, occupy parts of the northeast and northwest corners of the township and form small patches elsewhere. Two dikes of approximately andesitic composition occur in sec. 22.

STRUCTURE.

Nearly a third of the township in the western and southwestern parts is covered with late sedimentary rocks and solidified lavas. The remainder of the township is marked by a great complexity of structure in which faulting plays the predominant part, although complex folding has also occurred. The structural relations postulated are shown in structure sections A–B, C–D, E–F, and G–H (Pl. V).

Folds.—The chief structural feature of the phosphate deposits is a portion of the great anticline that occupies so much of T. 4 S., R. 37 E. The Thaynes group swings in a long curve from sec. 36 to sec. 30 but is more or less broken by faults, especially in the southeast corner of the township. A series of more or less broken folds which trends northwestward and is mostly inclined or overturned toward the northeast occupies the remainder of the township.

Faults.—Both normal and reverse faults are present, but it is thought that the reverse faults have had the larger influence in the distribution of the rocks. The normal faults are chiefly associated with the northeastern end of the great anticline mentioned above, where they have produced many offsets, particularly in the Thaynes group. Some of these faults are illustrated in structure section E–F (Pl. V). Other normal faults offset the main structures elsewhere in the township, as in secs. 2 and 3. The other faults may



EXPLANATION

SEDIMENTARY ROCKS

Pleistocene

Qoal

Older alluvium

TQ

Deposits of volcanic ash, hill-wash, etc., forming rounded hills and sloping benches

QUATERNARY

TERTIARY

UNCONFORMITY

Jtc

Twin Creek limestone

(Laminated gray shaly limestone and yellow calcareous sandstone)

UNCONFORMITY ?

Jn

Nugget sandstone

(Bright-red and light-colored sandstones)

JURASSIC

UNCONFORMITY ?

Ћws

Wood shale

(Bright-red shale, weathering to red soil)

Ћd

Deadman limestone

(Gray to purplish dense limestone of almost lithographic quality in places, with some gray and greenish chert)

Ћh

Higham grit

(Coarse pink to white gritty or conglomeratic sandstone)

TRIASSIC(?)

UNCONFORMITY

conveniently be described in connection with the structure sections that illustrate them.

In structure section A–B (Pl. V) the faults are all interpreted as reverse. In sec. 10 the Nugget sandstone, together with the underlying Wood shale, Deadman limestone, Higham grit, and Timothy sandstone, are thrown into a series of small folds that are broken by faults. The yellow sandstone in the NE. ¼ sec. 10 is assigned to the Timothy on lithologic grounds, and therefore faults must separate it from the Nugget on either hand. There is some doubt as to the structure of the Twin Creek limestone in sec. 1 because of insufficient knowledge of the stratigraphy of that formation. The structure is, however, provisionally interpreted as synclinorial and as inclined northeastward. Along the northeast limb of the synclinorium, in the very northeast corner of the township, thin platy sandstones like those of the lower portions of the Nugget sandstone emerge from beneath the lava and lie above massive beds of Twin Creek limestone that are believed to represent the upper part of the formation. If these assignments are correct, a fault must lie between the two formations, and the Nugget here appears to be thrust southwestward over the Twin Creek.

In structure section C–D (Pl. V) the faults are interpreted as reverse. North of the center of sec. 22 the Timothy sandstone becomes abnormally narrow. Between it and the Higham grit belt a narrow zone on the hillside is strewn with fragments of andesite, although no ledge of this rock appears. The andesite here is doubtless weathered from a small concealed dike that comes in along the contact of the two formations and probably marks the trace of a minor fault, as indicated. Near the north line of sec. 22 the Nugget sandstone comes in contact with thin-bedded shaly Twin Creek limestone. These beds are probably not the basal beds of the formation, for in sec. 1 similar beds are underlain by perhaps 800 feet of yellow calcareous sandstones with associated beds of gray limestones, some of which are crowded with oyster shells. In sec. 22 and in the NW. ¼ sec. 23 these thin-bedded, shaly limestones have been metamorphosed and in sec. 22 there is also a small andesite dike. These facts indicate that the contact between the Nugget sandstone and the Twin Creek limestone is a fault and the direction of thrusting is believed to be toward the south.

Immediately north of the fault just mentioned a small rocky point in the valley has ledges of massive gray limestone that carry fossils which have been identified by G. H. Girty as indicative of the Portneuf limestone. Faunally and lithologically these beds are different from those either south or north. They are interpreted as being pushed up between thrust faults and wedged between two areas of Twin Creek limestone, for the ledges in the rocky point to the east

carry an abundance of oyster shells. These "oyster beds" are repeated on the north side of the main valley in a series of low points along the valley side but have a somewhat different strike and dip. The discordant relations of the oyster beds appear to be due to faulting rather than to folding, and the fault is interpreted as reverse because of its relations to the Twin Creek area as a whole. An alternative view is offered in paragraph 1, below.

The contact of the Twin Creek limestone with the Nugget sandstone on the north is also regarded as a reverse fault because of the lack of accord in dip in neighboring outcrops of the two formations and because the Twin Creek bears no other evidence of unconformable relations with the Nugget. The structure of the areas of Twin Creek limestone is not clear. At least four interpretations may be offered:

1. The area may represent a relatively open and asymmetric syncline along the base of which movement sufficient to cut out some of the beds along the contact has taken place. If this interpretation is correct, the fault between the oyster beds might be normal. The interpolated Portneuf limestone and the relatively intense compression that seems to mark the region as a whole are unfavorable to this view.

2. The area may be in general a syncline that is overturned northeastward. This is in accord with the prevalent structure of the region but disagrees with the arrangement of the broken minor folds involved.

3. The syncline may be inclined southwestward. This interpretation is in accord with the arrangement of the minor folds in both the Twin Creek limestone and the adjacent Nugget on the southwest but disagrees with the inclination of the folds in the Thaynes farther southwest.

4. The Twin Creek and adjacent Nugget beds to the southwest may be part of a broken fan-shaped synclinorium that is bounded on the north by the Nugget overthrust toward the southwest and on the south by the Thaynes anticline, which is overthrust toward the northeast. This view is favored by the arrangement of minor folds and is in accord with the interpretation suggested for the Twin Creek area that is cut by the section A–B (Pl. V). It is represented in the section C–D (Pl. V).

In the structure section G–H (Pl. V) the first fault encountered is normal and offsets formations of the Thaynes. It is possible that the convergence of the two faults shown immediately to the west may influence the zone traversed by the section, but there is no evidence of such influence. In sec. 25 the Portneuf limestone is faulted against the Nugget sandstone, and this in turn against the Higham

grit by faults interpreted as thrusts toward the northeast. In the NE. ¼ sec. 25 a broad undulating syncline of Higham grit with Deadman limestone and Wood shale is cut off on the northwest by a fault that appears to be the continuation of one of the normal faults to the southwest. This fault is also shown in the structure section E–F (Pl. V).

In sec. 24 there are two areas of Portneuf limestone which are bounded by faults and apparently surrounded by Nugget sandstone. The relations of these limestone areas to the Nugget are not clear. The limestone is traversed by several small, relatively open folds. Though the western terminations of these areas are uncertain because of cover of float and soil from the Nugget the eastern terminations are clearly defined by exposures of the Nugget sandstone. At least two interpretations of their structure may be suggested. (1) These areas may represent parts of a once larger overthrust block that elsewhere has been eroded away, unless the small area of Portneuf limestone in secs. 15 and 22 is so considered. Though a great overthrust has occurred in the older Paleozoic rocks to the south and southwest and though the Triassic rocks in this and adjoining townships have been greatly disturbed, no thrust capable of producing the lateral displacement that would be required to place the postulated block in its present position has been observed elsewhere in the area occupied by the post-Paleozoic rocks. (2) These areas may represent subordinate anticlinal areas thrust upward into the Nugget synclinorium. A similar structure seems to have occurred in connection with the Higham grit in the townships to the east and southeast and might be expected in the present locality. This interpretation is provisionally shown in the structure-section sheet (Pl. V) as more in accord with the structural habit of the region.

In sec. 13 a belt of Higham grit is indicated, though much of its course in this section is concealed by soil, because of the occurrence of Higham grit in the southeast corner of the section and again in the NW. ¼ NW. ¼. It is assumed that the structural relations observed in connection with this belt to the southeast continue into this township.

The other structural features shown in the section are continuations of those in the townships to the east and southeast.

Covered area.—Carboniferous rocks, probably of the Wells formation, enter sec. 31. Northward the stratigraphic succession, as indicated by the limestone ridge in secs. 30, 29, and 20 and by local exposures still farther north, appears to be the same as that already described. In secs. 4, 9, 16, and 15 the large rounded hills are more or less soil covered, but there are many exposures of the Nugget sandstone. There has doubtless been both folding and faulting,

but not enough is known of these features to warrant any attempt at interpretation.

PHOSPHATE DEPOSITS.

Where the strata lie horizontal the depth of the phosphate bed below the base of the Timothy sandstone, according to the thicknesses assigned to the intervening formations, would be approximately 5,000 feet.

The Thaynes group enters sec. 36 and sweeps across the township in a flat curve, the last exposure being in sec. 30. On account of the complexities of structure shown in structure sections C–D and G–H (Pl. V), it seems probable that in some places steep dips within the Thaynes area would carry the phosphate bed below the depth of 5,000 feet, and in other places thrust faults would perhaps cut the bed out. For these reasons the boundary of the area estimated to contain phosphate at depths less than 5,000 feet is assumed to lie about half a mile southwest and south from the contact of the Portneuf limestone and the Timothy sandstone.

In secs. 24, 15, and 16 the Thaynes areas are so small and the structure so doubtful as not to warrant any estimate of their phosphate content.

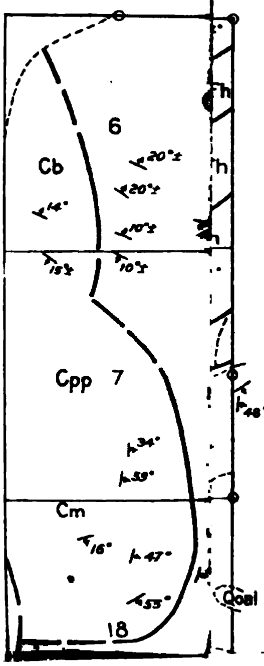
From sec. 12 northwestward a band of Portneuf limestone occurs, but here again the structure as shown in structure section A–B (Pl. V) is complex. Whatever phosphate deposits may be present are near the depth limit and occupy a relatively narrow band, the position of which can not be accurately determined from present data.

It is estimated that 4,520 acres in this township, practically all of which are in the basin of Lincoln Creek, are underlain by phosphate deposits at depths less than 5,000 feet.

In the NW. ¼ NE. ¼ sec. 11, T. 4 S., R. 37 E., the phosphate bed is 76 inches thick and shows an average content of 33.73 per cent of phosphorus pentoxide (P_2O_5), equivalent to 73.75 per cent tricalcium phosphate ($Ca_3(PO_4)_2$). (See p. 86.)

In the NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., a similarly rich bed measures 66 inches in thickness, and in the NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., the bed is 73 inches thick and of a similar high quality. (See p. 103.)

For this township it seems fair to assume a phosphate bed 6 feet thick that averages 70 per cent tricalcium phosphate. If the weight of 1 cubic foot of high-grade phosphate rock is taken as 180 pounds, 4,520 acres underlain by a 6-foot bed would yield in round numbers 94,925,800 long tons of high-grade phosphate rock. This estimate is on the assumption that the rocks are horizontal. They are, however, inclined at different angles, and the total amount is probably



EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY

Pleistocene

Qoal

Older alluvium

TQ

Deposits of volcanic ash, hill-wash, etc., forming rounded hills and sloping benches

TERTIARY

Pliocene?

Tsl

Salt Lake formation

(Conglomerate, marl, limestone, clay, and interbedded volcanic ash)

UNCONFORMITY

TRIASSIC

Lower Triassic

Thaynes group

TRfh

Fort Hall formation

(Yellowish and grayish siliceous and cherty limestones and calcareous sandstones)

TRr

Ross Fork limestone

(Dense gray thin-bedded limestone, olive-drab platy calcareous shales, purplish-gray thin and massively bedded limestone)

TRw

Woodside shale

(Olive-drab platy calcareous shales with interbedded reddish-brown limestones, more numerous near top)

UNCONFORMITY ?

Permian

Cpr

Cp

Phosphoria formation

(Phosphatic shales, impure limestone, and

greater. This excess may perhaps be counterbalanced by loss due to faulting or shearing of the beds in the process of their dislocation.

UTILIZATION OF THE LAND.

The township as a whole is best adapted to grazing. The lower benches near Lincoln Creek and northward could probably be dry farmed.

T. 4 S., R. 37 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line Railroad runs about 12 miles west of T. 4 S., R. 37 E. A road from sec. 3 leads northwestward 12 miles to Blackfoot and from sec. 32 a road leads southwestward and westward along Ross Fork Creek to Fort Hall, a distance of 15 miles or more. Both roads have easy grades, but the Blackfoot road traverses deep sand as it approaches Blackfoot River. The main road eastward along Ross Fork Creek enters the township in sec. 34. It crosses the divide in sec. 35 and descends to the Portneuf Valley.

GEOLOGY.

STRATIGRAPHY.

The rocks of the township are chiefly sedimentary, and range in age from Cambrian to Quaternary. A detailed geologic map of the township with structure sections is shown in Plate VI. A single dike of rhyolite, indicated by small patches and groups of boulders, lies near the western edge of the township in secs. 30 and 19.

The Cambrian and Ordovician rocks are confined to the rough wooded ridge along the west border and occupy only a small area in this township. They are dark limestones much shattered and veined. Silurian and Devonian rocks have not been recognized in this township, though fossils of doubtful Threeforks age were found in sec. 12, T. 4 S., R. 36 E.

Carboniferous rocks apparently underlie more than half of the township, though much of their area is concealed by Tertiary and Quaternary deposits. The Wells formation (Pennsylvanian) constitutes most of this area, although along its eastern border the Phosphoria formation (Permian) forms an important band, and in the northwestern part of the township both the Brazer and Madison limestones are found. The boundary between the last two formations has not been determined.

The Phosphoria formation is well developed. The phosphatic shale member is about 150 feet thick but forms a relatively broad band

because of its low dip. Its course is easily traced much of the way by float of high-grade phosphate. The Rex chert member is chiefly represented by the flinty shale facies, though locally there are ledges of massive chert, as in the NE. ¼ SE. ¼ sec. 11. An interesting and new facies of the Rex that is lithologically similar to the overlying Woodside was discovered in the SW. ¼ NW. ¼ sec. 2 and has been described elsewhere (p. 41). The thickness of the Rex, as estimated from its dip and relations to other members of the section, is about 350 feet.

The Woodside shale is largely faulted out in secs. 23 and 14, and the Rex chert there lies against the Ross Fork limestone of the Thaynes group. Elsewhere the Woodside shale appears to occupy its normal position in the section, but its upper boundary is somewhat uncertain because of the difficulty in finding the *Meekoceras* zone. This zone has been located, however, in a number of places. The Woodside shale has a thickness of about 900 feet in the SE. ¼ sec. 2, where a section was measured northeastward up the hill and both boundaries were fairly distinct.

Only the two lower formations of the Thaynes group are represented in this township—the Ross Fork limestone, 1,300 feet thick, and the Fort Hall formation, 800 feet or more thick.

The Tertiary rocks form a blanket that covers large areas in this township. In the SW. ¼ sec. 31 there is a conglomerate that is composed chiefly of Triassic materials in a white calcareous matrix which has been differentiated and tentatively correlated with the Salt Lake formation. Doubtless much of the Tertiary area would be found to consist of similar materials if it was exposed. In the NE. ¼ SE. ¼ sec. 21 the conglomerate is deep red and in appearance resembles the Eocene conglomerates of the Montpelier quadrangle farther southeast. Like the similar conglomerate in sec. 1, T. 5 S., R. 36 E., it has nothing to support the suggested correlation except its color and the fact that it contains a larger proportion of pre-Triassic rocks than the other conglomerates that are exposed.

Quaternary deposits occupy relatively small areas along some of the streams.

STRUCTURE.

The structure of the township is complex and involves folding and faulting of both the normal and reverse types. Nearly one-fifth of the township is concealed by deposits of probably late Tertiary and Quaternary age.

Folds.—The main structural feature of the area is a large anticline that pitches gently northeast and is broken by faulting along its southeast border and in the axial region toward the northeast. The north and northwest borders are concealed. The core of this anticline is composed of Carboniferous limestones, chiefly of the

Wells formation, which show minor folds and faults, the details of which have not been worked out. The succession of formations and the structural relations at the tip of the anticline are illustrated in structure section E–F (Pl. VI). The main structural feature of the eastern part of the township, including sec. 13 and the sections to the south, is probably an anticline that has been faulted around the western tip and broken by a lateral fault. The rocks of this portion of the region are Triassic (Woodside and Ross Fork limestone). The boundaries of these two formations have been drawn on the basis of the strikes of the observed exposures and the few discoveries of the *Meekoceras* zone.

Faults.—Along the west border in sec. 19 ancient Paleozoic rocks of Cambrian and Ordovician (?) age lie against Carboniferous limestones (Wells to Madison). The ancient limestones are much shattered and veined with calcite, and along the contact zone are linear patches and boulders of rhyolite. In sec. 18 the Madison limestone lies against the Wells formation in apparent fault relation. This fault is interpreted as a branch of the main fault between the older and the later rocks.

In the NW. ¼ sec. 30 the lower limestones of the Wells formation lap around the Cambrian and Ordovician limestones at the south extremity of the rough west border ridge. The contact region where visited was concealed, but the fault interpretation is here preferred because of the highly brecciated condition of the older limestone series.

In secs. 31 and 32 there is a pronounced gap between limestone hills that may be in part of structural origin. It is in line with the main fault zone noted above, and it seems likely that a branch of this great fault may pass through the gap, as suggested in the description of T. 5 S., R. 37 E. (p. 90). The beds in the east hill rise stratigraphically to the west, whereas those in the west hill, which dip both easterly and westerly, are upper Mississippian or perhaps older Wells. There is scant room, unless a sharp anticlinal fold be assumed to that underlie the ascending series on the east. A fault is tentatively pass through the west hill, for these limestones to connect with those placed here in the structure section A–B (Pl. VI).

In sec. 33 a fault enters the township from the south along the east flank of the big limestone hill. Though its trace is concealed, the fault appears to be required by the proximity to the lower Wells of the Phosphoria formation, concealed here but partly exposed in the SE. ¼ sec. 4, T. 5 S., R. 37 E. The supposed structural relations are shown in structure section A–B (Pl. VI).

In sec. 36 faults enter from adjacent townships. These faults are briefly discussed in the descriptions of T. 5 S., Rs. 37 and 38 E. (pp. 90, 102).

In sec. 25 a fault appears to offset the Woodside shale and the Ross Fork limestone. It is possible that this fault may continue through sec. 27 and account for the relations of the Phosphoria formation and the Ross Fork limestone on opposite sides, respectively, of the broad valley in sec. 27. An alternative interpretation of this last feature is that the apparent termination of the Phosphoria may be due to the presence of a cross anticlinal axis, which causes the formation to turn back beneath cover toward the SE. ¼ sec. 21, where beds of the Phosphoria are exposed. In support of this view it may be noted further that phosphate float appears abundantly in connection with two exposures of weathered Tertiary (?) conglomerate, which may overlie parts of the Phosphoria formation in the NE. ¼ SE. ¼ sec. 21. The Phosphoria beds in the SE. ¼ SE. ¼ sec. 21, however, appear more like an isolated area, as if caught in a small syncline.

In secs. 23 and 14 the Ross Fork limestone abuts against the Rex chert in what appears to be a thrust fault. In secs. 22 and 15 heavy-bedded limestones of the Wells formation strike almost at right angles to the course of the phosphate shales, as determined by the distribution of phosphate float along the hillsides. Here, again, a thrust fault is postulated. The supposed relations of both these faults are shown in structure section C–D (Pl. VI).

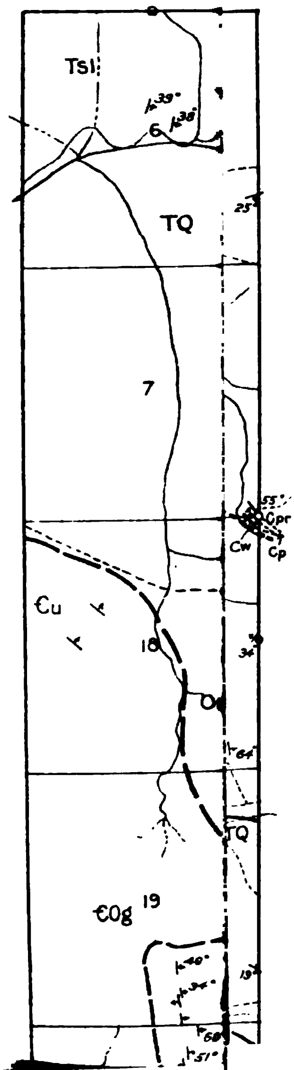
In the northeast corner of the township, in the marginal region of the great anticline of Carboniferous limestones, the overlying formations are cracked into numerous blocks by faults that are interpreted as normal and that produce offsets. These faults receive topographic expression in deep subparallel valleys and notches between the high points and linear hills that are so conspicuous here and in the immediately adjacent region on the north. The structural relations here suggested are illustrated in structure section G–H (Pl. VI). It is possible that the easternmost fault represented in sec. 12 may be reverse and perhaps connected with the fault shown in sec. 14.

In the NE. ¼ NE. ¼ sec. 11 the zone occupied by the Phosphoria formation is concealed by a grassy slope, which is underlain with float of Rex and Woodside, together with much calcareous material, and the whole block appears to be offset toward the east.

PHOSPHATE DEPOSITS.

It is estimated that an area equivalent to 9,760 acres in the eastern part of the township is underlain by phosphate deposits at a depth of less than 5,000 feet.

At station M 316, NW. ¼ NE. ¼ sec. 11, a section of the phosphate bed was made and samples were collected showing 76 inches of rock phosphate without notable partings and averaging 33.73 per cent



EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY

Pleistocene

Qoal — Older alluvium

TQ — Deposits of volcanic ash, hill-wash, etc., forming rounded hills and sloping benches

TERTIARY

Pliocene (?)

Tsl — Salt Lake formation *(Conglomerate, marl, limestone, clay, and interbedded volcanic ash)*

UNCONFORMITY

TRIASSIC

Lower Triassic — *Thaynes group*

Ћfh — Fort Hall formation *(Yellowish and grayish siliceous and cherty limestones and calcareous sandstones)*

Ћr — Ross Fork limestone *(Dense gray thin-bedded limestone, olive-drab platy calcareous shales, purplish-gray thin and massively bedded limestone)*

Ћw — Woodside shale *(Olive-drab platy calcareous shales with interbedded reddish-brown limestones, more numerous near top)*

UNCONFORMITY (?)

CARBONIFEROUS

Permian

Cpr / Cp — Phosphoria formation *(Phosphatic shales, impure limestones, and phosphate rock, with Rex chert member (Cpr) at top)*

UNCONFORMITY IN PLACES

Pennsylvanian

Cw — Wells formation *(Chiefly massively bedded cherty gray limestone; sandy beds toward top; siliceous dense and cherty gray limestone at top)*

Mississippian

Cb — Brazer limestone *(Massively bedded gray and drab limestone)*

UNCONFORMITY

ORDOVICIAN

Upper Ordovician

Ofh — Fish Haven dolomite *(Gray to brown, dark-weathering dolomitic limestone, much shattered and veined, somewhat cherty; Richmond fossils)*

UNCONFORMITY

P_2O_5, equivalent to 73.76 per cent tricalcium phosphate. (See p. 82.) In the NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., and in the NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., similarly high-grade beds were found to be 66 and 73 inches thick, respectively. (See pp. 91, 103.) The assumption of a 6-foot bed of high-grade rock for this township seems fair. The weight of such rock is assumed to be 180 pounds to the cubic foot, as in previous estimates. On this basis 9,760 acres underlain by a 6-foot bed would yield approximately 204,977,800 long tons of phosphate rock if the beds were horizontal. As the beds are not horizontal this estimate is too small. On the other hand, the folding and faulting of the beds may have occasioned some loss in quality or quantity to offset the gain due to inclination of the beds.

UTILIZATION OF THE LAND.

Much of the township is high and has rocky hills, though there are broad open valleys. The township as a whole is best adapted for grazing. Some of the lower slopes could perhaps be dry-farmed. A small area in secs. 28 and 29 could perhaps be drained and irrigated. It is now more or less marshy and has a heavy, somewhat alkaline soil.

T. 5 S., R. 37 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line Railroad runs 12 to 15 miles west of T. 5 S., R. 37 E. The road from Fort Hall east to the Blackfoot Dam and points south runs along Ross Fork Creek in the north part of the township and two roads run southeast from sec. 16 through secs. 24 and 25 to the Portneuf Valley and Soda Springs. The south two-thirds of the township is high, rugged, and timbered, and is occupied by the Mount Putnam ridge and its associated hills.

GEOLOGY.

STRATIGRAPHY.

The geologic features of this township are shown on Plate VII.

With the exception of the patch of rhyolite in the NE. ¼ sec. 15 and vicinity all the rocks of the township are sedimentary and range in age from Lower Cambrian to Quaternary.

In the south half of the township the rocks are mainly Cambrian. The various members have not been differentiated, but certain resemblances between the rocks of this township and those of Walcott's

Cambrian section near Liberty,[71] in the Montpelier district, make it probable that many if not all the members of that section may be represented here. The most important Cambrian rock topographically is the Brigham quartzite, which is a massive pinkish to purplish or dark-red vitreous quartzite, often gritty or conglomeratic. Other members of the Cambrian are lustrous shales, grayish or reddish, together with dolomitic and well-crystallized limestones, with some shaly limestones.

The line between the Cambrian and Ordovician has not been determined in this township, but it is probable that here, as in the Montpelier district, it falls in the limestone series below the white vitreous Swan Peak quartzite. This quartzite lies in patches over Brigham quartzite and other Cambrian and Ordovician formations. It seems once to have overspread much of the south half of the township, probably as part of a great overthrust block now separated by warping and erosion into detached masses. Ordovician limestones lie above the Swan Peak quartzite, as in the SE. ¼ SE. ¼ sec. 16, but they have not been differentiated from other members of the series.

No Silurian or Devonian rocks have been recognized in this township.

An area of doubtful rocks occupies the SE. ¼ sec. 24 and extends northwest. The rock is red or pinkish calcareous sandstone, somewhat quartzitic in places, and with shaly beds. It does not appear to agree with the lithology of either the Brigham or Swan Peak quartzites. It might represent the Worm Creek quartzite member of the Upper Cambrian St. Charles limestone in the Montpelier district, but this member has not elsewhere been recognized in such mass in this district. It has tentatively been grouped with the Wells formation of the Carboniferous, which it resembles to some extent lithologically and which is represented in the ridge to the east in T. 5 S., R. 38 E. In a search a mile along the ridge no fossils were found. Its final assignment must await further study.

Carboniferous rocks are found is secs. 1 and 4 and in the NE. ¼ NE. ¼ sec. 13. They include representatives of the Brazer limestone (?), Wells, and Phosphoria formations, but they are separated by faulting. The Phosphoria formation outcrops clearly in the NE. ¼ NE. ¼ sec. 13 where the phosphate bed has been studied and sampled. (See p. 91.) The Rex chert member of the Phosphoria occurs in the flinty shale facies. In the NE. ¼ SE. ¼ sec. 4 phosphate float and chert float are so disposed as to suggest that the material is in place. These areas, however, are surrounded by the Tertiary cover and no actual ledges of the Phosphoria are visible, but in the northern patch a ledge, supposed to represent the upper Wells, was

[71] Walcott, C. D., Nomenclature of some Cambrian Cordilleran formations: Smithsonian Coll., vol. 53, No. 1, pp. 5–9, 1908.

found. The phosphate shales and Rex chert are estimated from measurements in T. 4 S., R. 37 E., to be 150 and 350 feet thick, respectively.

The Woodside shale enters the township in the NW. ¼ sec. 1, where it appears to be faulted. The *Meekoceras* zone has not been found in this township but has been found in secs. 35 and 36 in the township to the north. The thickness of the Woodside shale is estimated to be 900 feet.

The Ross Fork limestone and the Fort Hall formation, both of which are composed predominantly of calcareous shale, represent the Thaynes group in this township. The lower part of the Ross Fork limestone has conspicuous beds that form fine cliffs in secs. 1 and 3. The shales of the Fort Hall formation are dense and resist erosion, so that they form conspicuous hills in the SE. ¼ sec. 1. The thickness of the Ross Fork limestone is estimated at 1,300 feet, and that of the Fort Hall formation at more than 800 feet.

In sec. 6 a conglomerate, which is composed chiefly of Triassic material and a white calcareous matrix, is tentatively assigned to the Salt Lake formation and correlated with the Salt Lake beds of Hayden and Peale of probable Pliocene age. This conglomerate is included by St. John in his Carboniferous section.[72] The Tertiary deposits include sloping bench lands that yield a white calcareous soil and are overspread with gravels probably of Quaternary age but not differentiated. A small area of Quaternary deposits forms meadowland in the NE. ¼ sec. 9 and vicinity.

STRUCTURE.

The old Paleozoic rocks of the township are thrown into folds and apparently much faulted. Nearly a quarter of the area is concealed beneath deposits of probable Tertiary and Quaternary age. It was not practicable to work out the details of this highly complex structure. Only the broader features are described.

Folds.—The northwestern phosphate-bearing syncline of T. 5 S., R. 38 E. (section A–B, Pl. X), enters the northeast corner of this township, but in sec. 1 a cross anticlinal axis enters from the northeast, and the strike of the ledges swings from northwest to a little south of west. In the NW. ¼ sec. 1 this cross fold is accompanied by a fault, which appears to be necessitated by the strike relations of the *Meekoceras* zone in secs. 35 and 36, T. 4 S., R. 37 E.

Folding occurs in places in the older rocks of the township. The geologic section A–B (Pl. VII) shows the postulated structure of the Cambrian and Ordovician rocks in the north part of secs. 22

[72] St. John, Orestes, U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, p. 329, 1879.

and 23. An anticlinal axis that trends northward apparently passes through secs. 20, 29, and 32.

Faults.—Faults have played an important part in the geologic structure of the township, and a number of faults are shown on the map, but further detailed stratigraphic study will be necessary before some of the relationships can be fully determined, and other important features are concealed beneath the broad covered areas in Ross Fork Valley and its tributaries.

The Putnam thrust (p. 62) is the most striking structural feature of the township.

In secs. 22 and 23 shales tentatively correlated with the lower part of Walcott's Cambrian section[73] appear to crowd too closely upon the Ordovician(?) quartzites and limestones on the north, and a thrust fault is therefore mapped as traversing the valley that heads to the southeast.

In sec. 24 the Ordovician(?) quartzite and limestones that occupy the ridge abut against the doubtful Carboniferous sandstones described above. Faults interpreted as reverse are therefore tentatively mapped on the southwest and northeast of these sandstones. The supposed structural relations are indicated in the geologic section C-D that accompanies the map of T. 5 S., R. 38 E. (Pl. X, p. 100).

In secs. 12 and 13 Cambrian and Ordovician limestones descend on the north to a broad valley that is occupied by later sediments. Triassic beds rise along the north side of this valley. The fault that here separates the early Paleozoic from the Triassic rocks is interpreted as a thrust and is concealed in the valley, but its postulated trace is indicated for a short distance on the map.

In secs. 9 and 10 the Cambrian and Ordovician rocks form a prominent point that terminates in a low cliff on the south side of Ross Fork Valley. Nearly a mile away to the north and in the general direction of the strike of the older rocks the Wells formation rises abruptly in high hills. The relations here suggest faulting, and a portion of the trace of such a fault is tentatively shown. This fault may prove to be continuous with that in secs. 12 and 13.

In sec. 4, along the east side of the prominent limestone hills, the lower part of the Wells formation abuts against the Phosphoria, which is largely concealed. There appears not to be space for the sharp fold that would be required to bring the upper Wells into normal relations with the Phosphoria, hence it appears that a fault, probably a thrust, marks the boundary of the Wells and Phosphoria in this section.

In sec. 5 is a broad gap between limestone hills. On the east side beds of the Wells formation ascend stratigraphically to the west.

[73] Walcott, C. D., op. cit., pp. 5-9.

On the west side of the valley are beds of the upper Mississippian or lower Wells which dip in some places to the east and in others to the west. This gap is in line with a well-recognized fault in the adjoining township on the north, which brings Cambrian and Ordovician limestones against Carboniferous limestones. The conditions at the gap suggest faulting, hence a fault is tentatively indicated on the map, although its position is indeterminate because of the cover of later sedimentary rocks.

Secs. 7 and 8 and the W. ½ sec. 6 are completely covered with Tertiary deposits. However, the large amount of Triassic débris included in the Tertiary deposits in sec. 6, together with the actual outcrop of Triassic beds in the southeastern part of T. 4 S., R. 36 E., the adjoining township on the northwest, indicates the proximity of Triassic sediments. Between these rocks and the Cambrian and Ordovician quartzites and limestones to the south and west there must be a fault, perhaps the continuation of the thrust in sec. 12. The extent of the cover in the sections named makes it impossible to represent the fault on the map.

In the SE. ¼ sec. 10 and the immediately adjoining portions of the neighboring sections there is a patch of rhyolite that forms the top of a prominent hill. The position of the rhyolite at a point toward which several of the faults named converge suggests that the locus of the outflow of the rhyolite may have been determined by the convergence or intersection of faults.

PHOSPHATE DEPOSITS.

The extensive cover in the northeastern part of the township causes some uncertainty as to the boundary of the phosphate and post-phosphate rocks. It is estimated, however, that about 3,120 acres are underlain by phosphate at depths less than 5,000 feet. In the NE. ¼ NE. ¼ sec. 13, close to the section corner, a trench that was made by the Survey party across the phosphate bed exposed 66 inches of phosphate rock without partings. Samples taken across the bed showed an average content of 33.96 per cent phosphorus pentoxide, equivalent to 74.20 per cent tricalcium phosphate. (See p. 87.) The weight of this rock, as shown by earlier determinations, is about 180 pounds to the cubic foot. On this basis 3,120 acres underlain by a 5½-foot bed would yield 55,744,200 long tons of high-grade phosphate rock if the strata were horizontal. The beds are, however, inclined at rather large angles, so that the actual amount of rock present should exceed the estimate. In view of the faulting and cover near the margins of the deposit, it is probably wiser not to add to the above estimate.

UTILIZATION OF THE LAND.

The high hills in the south half of the township afford excellent timber and pasturage. The smoother portions of the benches in the north part could be dry farmed and the lower slopes and meadows irrigated. In the SW. ¼ NW. ¼ sec. 5 an excellent stand of timothy was observed in connection with some unoccupied ranch buildings. In the SE. ¼ sec. 4 and vicinity there is a partly fenced meadow that is utilized for wild hay.

T. 3 S., R. 38 E.

TRANSPORTATION FACILITIES.

Roads in the southwestern and northwestern parts of T. 3 S., R. 38 E., lead to Blackfoot, 15 miles or more to the west, the most accessible railroad point. The southwestern part of the township is traversed by prominent ridges and deep valleys which have a difference in elevation of about 1,000 feet. In the northeastern part long, sloping benches cut by streams descend to Blackfoot River, which here occupies a picturesque walled canyon 200 to 300 feet deep in basalt.

GEOLOGY.

STRATIGRAPHY.

More than half the area mapped is underlain by igneous rocks and their derivatives. The sedimentary series includes only Triassic and Jurassic formations, and some of the Tertiary conglomerates. The geologic features of this township are shown on the map (Pl. VIII).

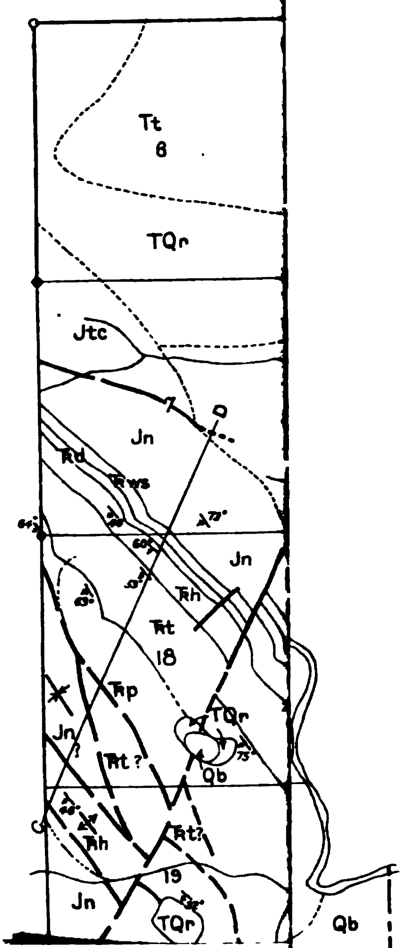
The oldest sedimentary rocks examined in this township belong to the Fort Hall formation of the Thaynes group. The rocks are calcareous shales with some sandy beds and some limestones. Above these comes the Portneuf limestone, which consists of cherty and siliceous limestones rather massively bedded and topographically resistant.

The Timothy sandstone above the Thaynes is a soft yellow, rather thin-bedded calcareous sandstone.

The Higham grit, Deadman limestone, Wood shale, and Nugget sandstone are characteristically developed in this township. Plate II, *A* (p. 18), shows a strike ridge formed by the Higham grit.

The Twin Creek limestone occupies two relatively small areas, one in secs. 6 and 7 and the other in secs. 27, 28, and 34.

The Tertiary rocks are whitish and yellowish calcareous conglomerates that are assigned to the Salt Lake formation of probable Pliocene age.



EXPLANATION

SEDIMENTARY ROCKS

TERTIARY AND QUATERNARY(?)

TQ

Deposits of volcanic ash, hill-wash, etc., forming rounded hills and sloping benches

Pliocene?

Tsl

Salt Lake formation

(Conglomerate, marl, limestone, clay, and interbedded volcanic ash)

UNCONFORMITY

JURASSIC

Jtc

Twin Creek limestone

(Laminated grey shaly limestone and yellow calcareous sandstone)

UNCONFORMITY ?

Jn

Nugget sandstone

(Bright-red and light-colored sandstone)

UNCONFORMITY ?

TRIASSIC(?)

Ꞧws

Wood shale

(Bright-red shale, weathering to red soil)

Ꞧd

Deadman limestone

(Grey to purplish dense limestone, of almost lithographic quality in places, with some grey and greenish chert)

Ꞧh

Higham grit

(Coarse pink to white gritty or conglomeratic sandstone)

UNCONFORMITY

TRIASSIC

Lower Triassic

Ꞧt

Timothy sandstone

(Sugary yellowish to grayish sandstone in thin beds)

UNCONFORMITY ?

Thaynes group

Ꞧp

Portneuf limestone

(Siliceous cherty grey to yellowish limestones in massive beds)

Ꞧfh

Fort Hall formation

(Yellowish and grayish siliceous and cherty limestones and calcareous sandstones)

The igneous rocks are rhyolites, andesites, andesitic tuffs, and basalts. From the relations in the township to the north it appears probable that the andesites and andesitic tuffs are the oldest, followed by the rhyolites and basalts, and that all are of late Tertiary or Quaternary age. A particularly interesting rock occurs in the SW. ¼ SE. ¼ sec. 18. This is the nepheline basalt that is described on page 58.

STRUCTURE.

Sedimentary rocks occupy the southwestern part of the township and are greatly disordered. Folding and faulting have occurred, but faulting is more conspicuous. The folds thus far recognized have all been faulted to a greater or less degree.

Fold.—The west limb of a large syncline that enters from T. 4 S., R. 38 E., passes from the SW. ¼ sec. 34 northwestward through sec. 7. This limb is inclined steeply westward and indicates that the syncline is asymmetric or overturned toward the northeast. The east limb of this fold is concealed beneath solidified lavas and fragmental volcanic rocks, and is probably more or less faulted, for in sec. 7 it is partly transgressed by a fault that passes beneath the cover. The west limb is marked by local minor folding and perhaps thrust faulting, for in several places patches of igneous rock lie along its course, and one of these, in secs. 28 and 29, is of considerable size. Also in sec. 18 this limb is offset twice by normal faults.

Southwest of this big syncline lies an area of Nugget sandstone with underlying formations in apparently synclinorial structure, though much faulted. Among these formations are two belts of Higham grit, which are interpreted as anticlinal, or perhaps in places as isoclinal, for in the southwest belt the Deadman limestone and Wood shale are absent through faulting, but the Nugget sandstone lies on each side of the belt. In the other belt, in secs. 32 and 29, the east side forms the east boundary of the synclinorium and the relation is not so clear, but farther northwest in secs. 19 and 18 this belt apparently has Nugget sandstone on each side without the Deadman limestone and Wood shale that should intervene.

In the same region also a band of Timothy sandstone apparently lies against the Nugget sandstone on the west and a somewhat narrow belt of the Portneuf limestone on the east. Faults are drawn on both sides of the Timothy here because on the west side the three formations below the Nugget are apparently missing, and on the east side there is not enough room for the Portneuf limestone. There is perhaps a little uncertainty in the identification of the Timothy here, for the determination is based on pieces of float that lie on a smooth slope, and there is sometimes difficulty in distinguishing pieces of the Timothy from some of the softer and more yellowish

beds of the Nugget sandstone. The same difficulty was encountered in two localities in the township on the west.

In sec. 31 the rock formations of the township become parts of a large northeastward-trending anticline that forms an important structural feature of T. 4 S., R. 37 E. The beds in sec. 31 curve around from southeast to northwest in response to the anticlinal structure, but the anterior part of the anticline has been spread by a number of normal faults that produce offsets and slight or moderate displacements.

Faults.—The principal fault is the one that separates the overturned syncline on the northeast from the Nugget synclinorium on the southwest. This fault is interpreted as a reverse fault, as are also the other strike faults, because of their intimate relations with the folds and because of the strong lateral compression that the rock formations have endured.

Normal faults cut these structural features at nearly right angles, particularly in the southwest corner of the township.

The main features of both groups of faults have already been mentioned in the discussion of the folding. The structure sections drawn along the lines A–B and C–D (Pl. VIII) illustrate the structural interpretations above outlined. The normal faults are illustrated in structure section G–H (Pl. VI, p. 82).

PHOSPHATE DEPOSITS.

As the exposed sedimentary rocks are all post-phosphate it is probable that phosphate beds underlie much of the township. The rock formations here represented are for the most part, however, far above the phosphate horizon, so that the phosphate rock would lie considerably deeper than 5,000 feet. A band of Portneuf limestone passes northwestward from sec. 33. This rock, if in normal position, would be underlain by phosphate within workable depths. However, it is overturned toward the northeast and faulted along its west border. It is doubtful, therefore, if any significant deposits of phosphate rock occur within 5,000 feet of the surface along this zone. In sec. 31 both the Portneuf limestone and the Fort Hall formation occupy a small area. These formations would both normally be underlain by phosphate deposits at less depths than 5,000 feet, but in view of the supposed folding and thrust faulting, as well as the normal faulting, it is doubtful if more than a few acres, if any, contain workable phosphate deposits.

UTILIZATION OF THE LAND.

The township as a whole is best adapted for grazing. Dry farming would perhaps be successful on the lower benches that slope toward Blackfoot River.

T. 4 S., R. 38 E.

TRANSPORTATION FACILITIES.

Blackfoot, on the Oregon Short Line, is 15 miles or more by road northwest of T. 4 S., R. 38 E. Bancroft, another railroad point, lies to the south about 20 miles by road. A stage line from Bancroft to Chesterfield comes within about 12 miles of the township. Fort Hall, a third railroad point, is 20 miles or more west of the township. Fairly good roads connect this township with each of these railroad points.

GEOLOGY.

STRATIGRAPHY.

Both igneous and sedimentary rocks are represented in the township. The sedimentary rocks range from Carboniferous (Wells formation) to Quaternary in age.

The Wells formation is confined to the southwest corner of the township, where it is involved in a number of broken folds.

The Phosphoria formation accompanies the Wells and appears to extend eastward under Tertiary and Quaternary deposits as far as the S. ½ sec. 22. Its northern limits east of the NW. ¼ NW. ¼ sec. 20 are not known because of cover and possible faulting. The outcrop of the phosphatic shales is confined to narrow bands in association with the Wells formation in the southwest corner of the township.

The Woodside shale accompanies the Wells and Phosphoria in the southwest corner and forms small patches elsewhere. It may perhaps underlie the Tertiary and Quaternary cover in secs. 21 and 28 and vicinity.

The Ross Fork limestone occupies three small areas in secs. 18, 22, 23, 26, 31, and 32. It may also underlie parts of the covered area in secs. 16, 17, 18, and 21, but of this there is no definite knowledge. The Fort Hall formation occupies a broad area in secs. 6 and 7 that extends and narrows eastward and southeastward. It makes the prominent ridge that extends from sec. 23 to sec. 9. The Portneuf limestone belt is separated from the Fort Hall formation by belts of Nugget sandstone and Higham grit[a] that are faulted between the two upper formations of the Thaynes group.

The Timothy sandstone, Higham grit, Deadman limestone, and Nugget sandstone outcrop with apparent conformity in belts that extend northwest from sec. 13. The Wood shale is believed to be present but was not differentiated from the overlying sandstones in this township, but the Deadman limestone was differentiated and

[a] On Plate IX the belt of Higham grit has inadvertently been mislabeled.

mapped. The failure to differentiate the Wood shale is probably due to the fact that at the time this township was mapped the subdivision of these rocks had not been considered, and the Wood shale was probably grouped with the overlying red sandstone. The belts of Nugget sandstone and Higham grit that lie between the upper members of the Thaynes are each faulted on both contacts.

The Twin Creek limestone is not exposed in this township but may underlie the igneous rock in sec. 2 and vicinity, for in T. 3 S., R. 38 E., it lies east of the Nugget sandstone and passes beneath similar igneous rock on the east.

In the southeast corner of the township there is a weathered conglomerate which consists of boulders and pebbles of the older sedimentary rocks and some solidified lavas. This conglomerate is tentatively assigned to the Salt Lake formation of probable Pliocene age.

The central part of the township and many of the slopes from the hills are covered with a deposit that yields a white calcareous soil and that is commonly more or less overstrewn with pebbles and rock fragments, which may have been in part weathered out from Pliocene (?) beds or perhaps in part rearranged by erosion. These deposits have not been differentiated but are probably mostly Tertiary, though possibly in part Quaternary.

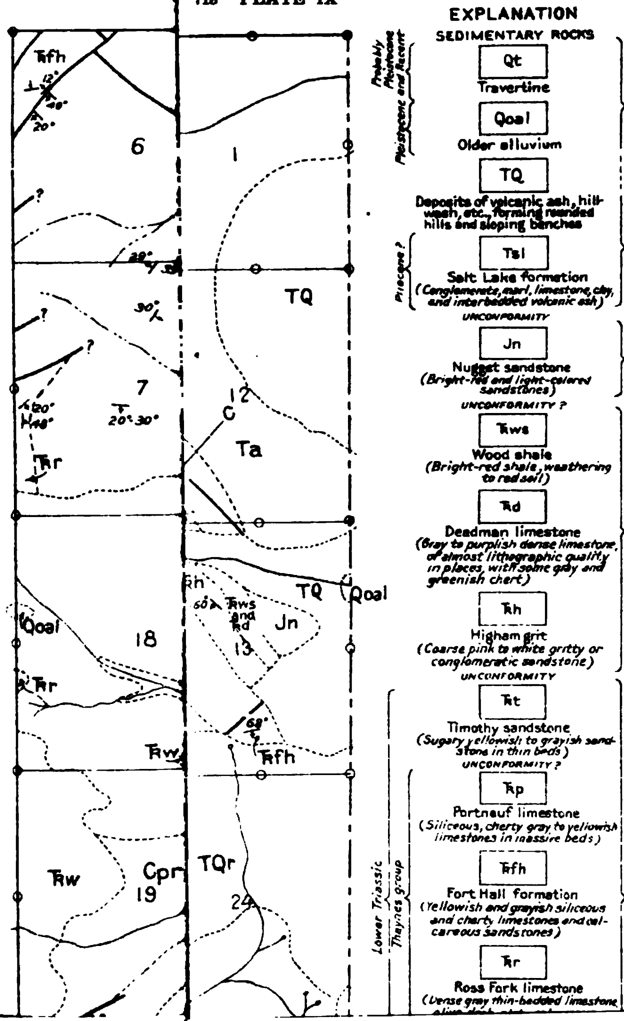
Quaternary alluvial deposits occupy the larger valley bottoms. In secs. 33 and 28 there are considerable deposits of travertine. In both areas springs are now associated with the travertine. The spring in sec. 28 is said to be thermal, but no temperature measurements were made.

The igneous rocks are intermediate or acidic and correspond approximately to andesite and rhyolite. They occupy extensive areas in the eastern half of the township and are either of Pliocene or Pleistocene age.

STRUCTURE.

The structure of the township is complex and its interpretation is rendered difficult by the large areas of late sediments and igneous rocks that conceal the older rocks beneath. The older rocks have been subjected both to folding and faulting, although the effects of the faulting are more conspicuous.

Folds.—The structural feature which has the greatest effect on the phosphate deposits is a broad, shallow syncline, which trends about N. 20° W. and which occupies the south-central part of the township. There is an element of doubt in the interpretation of this feature, because this portion of the township is occupied by a broad valley and is covered largely with late sediments. The occurrence of Rex chert apparently in place on the east and west sides of this valley,


EXPLANATION
SEDIMENTARY ROCKS
Qt
Travertine
Qoal
Older alluvium
Probably Pleistocene, Pleistocene and Recent
QUATERNARY
TQ
Deposits of volcanic ash, hill-wash, etc., forming rounded hills and sloping benches
Ts l
Salt Lake formation
(Conglomerate, marl, limestone, clay, and interbedded volcanic ash)
Pliocene?
TERTIARY
UNCONFORMITY
Jn
Nugget sandstone
(Bright-red and light-colored sandstones)
JURASSIC
UNCONFORMITY ?
Ꞧws
Wood shale
(Bright-red shale, weathering to red soil)
Ꞧd
Deadman limestone
(Gray to purplish dense limestone, of almost lithographic quality in places, with some gray and greenish chert)
Ꞧh
Higham grit
(Coarse pink to white gritty or conglomeratic sandstone)
TRIASSIC(?)
UNCONFORMITY
Ꞧt
Timothy sandstone
(Sugary yellowish to grayish sandstone in thin beds)
UNCONFORMITY ?
Ꞧp
Portneuf limestone
(Siliceous, cherty gray to yellowish limestones in massive beds)
Ꞧfh
Fort Hall formation
(Yellowish and grayish siliceous and cherty limestones and calcareous sandstones)
Ꞧr
Ross Fork limestone
(Dense gray thin-bedded limestone
Lower Triassic
Thaynes group
TRIASSIC
Ꞧfh
6
1
TQ
7
12
C
Ta
Ꞧr
18
Qoal
Ꞧws and Ꞧd
Jn
13
Ꞧw
Ꞧfh
Cpr
19
TQr
24

together with the abundant occurrence of fragments of float from the Rex in the later deposits, is thought to justify the view above expressed. Along the west margin of the syncline in secs. 32, 29, and 30 there is anticlinorial structure and overturning and overthrust faulting toward the northeast. On the east side the syncline is cut by a normal (?) fault that brings the Ross Fork limestone against the Rex in sec. 22. In the NW. ¼ NW. ¼ sec. 30 the phosphate beds are cut off by a fault that may prove to be a continuation of the fault just mentioned. The occurrence of successively higher formations to the northwest indicates a gentle pitch in that direction.

It is supposed that the northeastern part of the township, northwest of sec. 13, contains the west limb of a large overturned syncline, which involves formations that range from the Portneuf limestone to the Nugget sandstone. The east limb of this fold is concealed beneath andesite. The highest beds of the syncline exposed in this township are those of the Nugget sandstone, but in the township to the north the Twin Creek beds appear east of the Nugget and thus suggest a northwesterly pitch.

Along the southwest flank of the ridge in secs. 15 to 23 there is a synclinal fold in the Fort Hall formation, which is not overturned but has the steeper limb on the east side. Portions of other folds lie in the faulted Nugget sandstone and Higham grit on the east.

The folds above described are indicated in the structure sections drawn along the line A–B–C (Pl. IX).

Faults.—The faults appear to be chiefly of the reverse type and for the most part to have accompanied the folding. The fault that offsets the phosphate deposits in the NW. ¼ NW. ¼ sec. 30 is, however, apparently normal. It may be continuous with the fault in sec. 22 and with a postulated concealed fault in sec. 26, where similar structural conditions apparently obtain. Small normal faults enter the northwest corner of the township, but these are more fully described and illustrated in the description of T. 4 S., R. 37 E. (See Pl. VI.)

The Fort Hall formation is thrust upon the Nugget sandstone from the NE. ¼ NE. ¼ sec. 23 northwestward through secs. 5 and 6, where it transgresses other disturbed areas of the Nugget and Higham formations.

East of the Nugget sandstone but without the normally intervening Wood shale and Deadman limestone lies the Higham grit. Both the sandstone and the grit are broken and slickensided, and the sandstone seems to be overthrust upon the grit.

East of the Higham grit belt lies a series of Triassic beds, beginning with the Portneuf limestone, that dip steeply westward but

rise stratigraphically eastward. The accordance of the trend of this fault with the thrust faults and axes to the southwest renders unlikely its interpretation as normal, yet, as younger beds lie to the southwest, the interpretation as an overthrust would seem to imply movement from the northeast toward the southwest, which is contrary to the direction of thrust more commonly observed in this region. An alternative interpretation as underthrust is suggested, in which the older beds on the northeast have been underthrust beneath the younger beds to the southwest. The structure section B–C' (Pl. IX) shows that there is a tendency toward a rude fan structure suggested by the asymmetric syncline in the ridge immediately southwest and the supposed overthrust syncline on the northeast. Such a structure is favorable to the underthrust interpretation. Possible fan structure has been suggested in explanation of certain features in T. 3 S., R. 37 E., already described (p. 80). In sec. 5 two faults that are interpreted as thrusts pass beneath the overlapping block of the Fort Hall formation. These faults cut out the Wood shale and Deadman limestone that should normally intervene between the Higham grit and the Nugget sandstone.

The complex of faults in the southwestern part of the township is apparently an accompaniment of the overturned folding along the west border of the large syncline. These faults are interpreted as reversed faults.

In secs. 23 and 15 along the southwest flank of the ridge patches of rhyolite suggest a fracture and possible displacement of the beds. The dips and thicknesses of the beds involved do not, however, justify the interpretation of a fault there.

The fault relations suggested are illustrated in the structure sections drawn along the line A–B–C (Pl. IX).

PHOSPHATE DEPOSITS.

Although the Portneuf limestone, if horizontal, would be underlain by the phosphatic shales at depths somewhat less than 5,000 feet, that formation is both overturned and faulted in such manner as probably to preclude the occurrence of phosphate within the 5,000-foot limit in that belt. Southwest of the fault between the Fort Hall formation and the Nugget sandstone there is a broad belt that extends southeast across the township which is probably underlain by the phosphatic shales at depths less than 5,000 feet. Much of this area is covered by Tertiary and Quaternary deposits and some by igneous rock. There is also some disturbance in the structure, but the outcrops around the margin of the area suggest that the covered region is underlain by the lower postphosphate rocks rather than by prephosphate or higher postphosphate formations. After deducting the igneous areas, except the area in sec. 26, which is retained because

of the relative positions of the Rex chert and the Ross Fork limestone, and a zone half a mile wide along the fault northeast of the Fort Hall formation, it is estimated that 12,200 acres are underlain by phosphate at depths less than 5,000 feet.

In sec. 11, T. 4 S., R. 37 E., the phosphate bed includes 76 inches of material that has an average content of 73.76 per cent tricalcium phosphate ($Ca_3(PO_4)_2$). In sec. 13, T. 5 S., R. 37 E., the phosphate bed is 66 inches thick and has an average content of 74.19 per cent tricalcium phosphate, and in sec. 36, T. 5 S., R. 38 E., the phosphate bed is 73 inches thick and has an average content of 74.5 per cent tricalcium phosphate. (See pp. 87, 91, 103.) Although there are no exposures in T. 4 S., R. 38 E., it seems reasonable to infer from evidence in the neighboring townships the presence of a phosphate bed at least equal to the minimum thickness measured with a content of 70 per cent or more tricalcium phosphate. The weight of a cubic foot of such rock according to previous determinations is about 180 pounds. On this basis 12,200 acres underlain by a bed 66 inches thick would yield approximately 234,870,000 long tons of phosphate rock.

As a large part of the area containing phosphate is relatively low, receiving or transmitting drainage from the neighboring hills, it is probable that half to two-thirds of the tonnage above estimated may lie below groundwater level.

UTILIZATION OF THE LAND.

The alluvial bottoms and lower benches could be farmed, and water is available for a considerable part of it. The hills afford pasturage.

T. 5 S., R. 38 E.

TRANSPORTATION FACILITIES.

Bancroft, on the Oregon Short Line Railroad, is about 14 miles due south of T. 5 S., R. 38 E. The distance by road is somewhat greater. Fort Hall, another railroad point on the Oregon Short Line, is about 20 miles northwest of the township. Good roads lead to both these places. Stage and mail connections are maintained between Bancroft and Chesterfield, about 6 miles southeast of the township.

GEOLOGY.

STRATIGRAPHY.

The rocks of the township are chiefly sedimentary, but a few small patches of rhyolite occur in the northeastern part.

The sedimentary rocks range in age from Cambrian to Quaternary. The Cambrian and Ordovician rocks are not distinguished

here in mapping except the Swan Peak quartzite (Ordovician), which is topographically prominent in the western and southwestern parts of the township. The other members of the Cambrian and Ordovician are limestones and lustrous shales in the ridges in the southwestern part of the township.

Silurian rocks have not been identified in this area.

A single fossil collection in the NE. ¼ SE. ¼ sec. 29 was doubtfully assigned by Edwin Kirk to the Devonian Threeforks limestone. This collection was taken near a small fault that is not shown on the map. The neighboring rocks were determined as Madison limestone by G. H. Girty. The Devonian has not been differentiated from the Carboniferous in the mapping of this township.

All members of the Carboniferous are represented in the ridge of sec. 29 and vicinity, but, with the exception of the Phosphoria formation, none have been differentiated in the mapping because of the complex structure of the ridge and the detailed study necessary for such differentiation. An area of sandstone in the SW. ¼ sec. 19 has been doubtfully assigned to the Wells formation on lithologic grounds, but it may prove to be considerably older. The Wells formation underlies a large area in secs. 35 and 36 and occurs in more or less detached areas in the western ridge and in secs. 18 and 5.

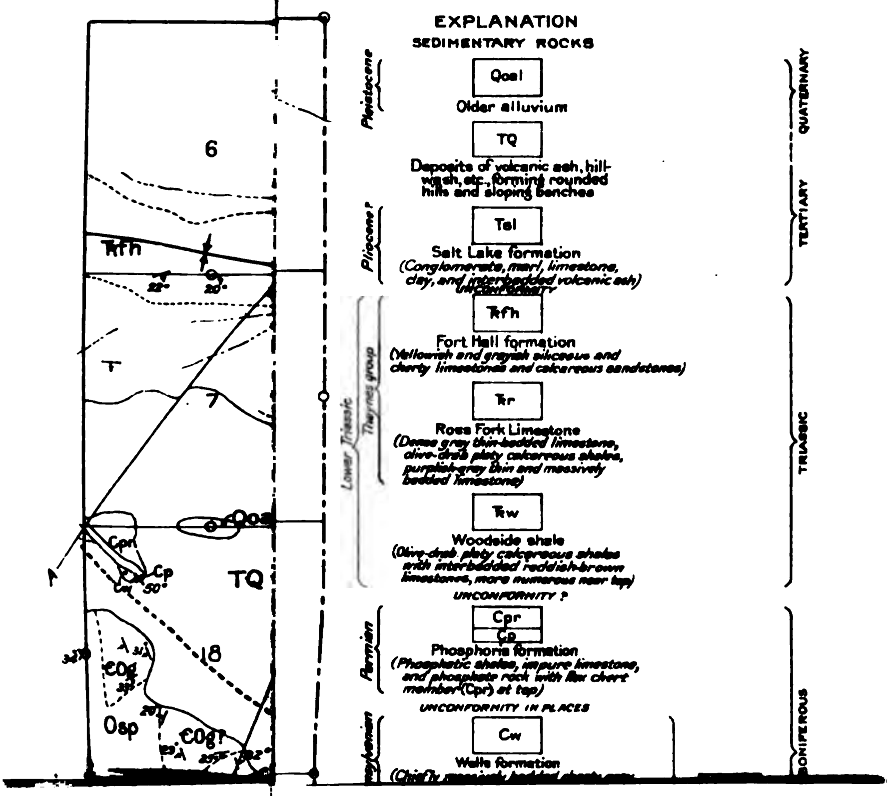
The Phosphoria formation occurs in faulted areas in the western ridge, in secs. 17, 18, 7, and 5, and in a large area in sec. 36 and vicinity. In secs. 28, 29, 32, and 33 the Rex chert member for characteristic massive chert beds. In sec. 29 the chert grades m or less into the limestone facies. Elsewhere the Rex chert has flinty shale facies. The phosphatic shales are best exposed in northwest corner of sec. 18 and in sec. 36.

The Woodside shale is exposed in the syncline in sec. 36 vicinity and doubtfully in the NE. ¼ sec. 5. It has not been rec nized elsewhere in the township.

The Thaynes group, in the northwest corner of the township represented chiefly by the Ross Fork limestone, but the higher h in the vicinity of the SW. ¼ sec. 6 carry the Fort Hall formation

Much of the township east of the Portneuf Valley is covered w a bouldery deposit that appears to be weathered from a late c glomerate and is tentatively correlated with the Salt Lake form tion of probable Pliocene age. The boulders in many places large, several feet in diameter, and angular. Many of them white quartzite of the Swan Peak type. They lie in different po tions and are apparently not in place, though they can not have be moved far. However, no ledges from which they might have com are exposed in the vicinity. Associated with these coarser deposi are beds of white marl with numerous gastropod remains. Exposur occur in the NW. ¼ sec. 15 and across the river near by. Much o

U. S. GEOLOGICAL X



the remainder of the township is covered by a bouldery and pebbly deposit, probably similar in origin to that just described but not definitely differentiated. This is probably chiefly Tertiary but may be in part of Quaternary age.

Alluvial deposits of Quaternary age form a relatively narrow belt along Portneuf River. They are usually rather distinctly separated from the Tertiary beds of the bench lands by steep slopes.

STRUCTURE.

The geologic structure of the township, where exposed, is complex and involves overturned folding and faulting, both of the normal and of the reverse types. Fully half of the township is concealed beneath a cover of late deposits, but it seems fair to conclude that the complexities noted elsewhere continue under this cover.

Folds.—The main structural features of the township, so far as the phosphate deposits are concerned, are parts of two synclines in the northwest and southeast corners respectively of the township. These two portions of synclines are possibly parts of the same general syncline and may be continuous beneath the cover. In view of the structural complexities of other parts of the township, the continuity of the syncline can not safely be assumed, although it may be noted that both parts are of similar type, namely, asymmetric, overturned toward the northeast, and faulted along the northeast border. The strike of the small exposure of the Thaynes group in the SE. ¼ sec. 8 and of the Wells formation in the SW. ¼ sec. 17 suggests that the northwest syncline is terminated somewhere near the middle of the township. This appearance may, however, be due to a cross anticlinal axis, such as that which turns the strike of the ledges to the south of west in sec. 6 and adjoining parts of the neighboring townships. The northeast border of this syncline is interpreted as a thrust because of its apparently irregular outline. The southwest border is marked by a minor fault in the SW. ¼ sec. 17. The structural features here suggested are shown in geologic section A–B (Pl. X).

The structure of the southeast syncline is shown in geologic section I–J (Pl. X).

Folding has also occurred in the complex ridge that extends southeastward from secs. 18 and 19. Here the folds are broken by many faults, and it has not been possible to work out the structure in sufficient detail to ascertain the number and character of the folds.

Faults.—Two large faults, interpreted as thrusts, are particularly noteworthy. The first separates the complex ridge with rocks ranging in age from Cambrian to Phosphoria from the adjacent phos-

phate-bearing syncline on the northeast. The trace of this fault is largely concealed by late sediments, but it is believed to enter the township in the NE. ¼ sec. 18 and to continue along the border and lower slopes of the ridge toward the center of the township. The position of these older rocks along the border of a large syncline that is inclined northeastward leads to the interpretation of this fault as a thrust the plane of which is inclined to the southwest. (See geologie sections A–B and C–D, Pl. X.)

The second important thrust crosses the ridge in the NE. ¼ sec. 32 and the NW. ¼ sec. 33, where it appears to have been slightly offset by normal (?) faults. Here the Cambrian and Ordovician limestones and shales lie against a complex of Permian (Phosphoria) and Pennsylvanian (Wells) rocks. The relationship is not entirely clear on the basis of present evidence, but the fault is tentatively interpreted as a thrust. (See geologic section G–H, Pl. X.)

The scant representation of Silurian and Devonian rocks in the Fort Hall region, together with the lack of opportunity to measure the thickness of the formations below the Phosphoria and the complex structure of the rocks involved, all make impossible any definite statement of the amount of dislocation produced by these thrusts. It seems safe, however, to infer that the dislocation may measure several thousand feet.

Additional faults in considerable number occur in the same ridge and some of these have been tentatively interpreted in sections G–H, E–F, and C–D (Pl. X). The complete determination of the structure here awaits more detailed and larger-scale studies than were practicable during the present investigation.

Other faults enter the township from the west, but these are more clearly shown in the adjacent township (T. 5 S., R. 37 E.). A brief discussion of them is given in the description of that township (p. 90).

PHOSPHATE DEPOSITS.

A thick bed of high-grade phosphate rock has been found and sampled in secs. 18 and 36. The outcrop of the phosphate shales in secs. 17 and 18 is alined well with that in sec. 36. Postphosphate rocks lie on the northeast side of this line. These facts suggest that much of the northeastern part of the township may be underlain by valuable phosphate rock within workable limits. However, the extensive cover and the complex structure of the exposed parts of the older sedimentary rocks make it unwise to estimate the phosphate resources of the covered area except of those parts relatively near the exposed areas. It is estimated that 8,120 acres are underlain by available phosphate rocks. The complexly faulted small areas of Rex chert in secs. 28, 29, 32, and 33 are not included in this estimate.

About 180 acres included in the above figures lie east of the reservation boundary in secs. 25 and 36.

In the prospect made by the Survey party just over the township line from the northwest corner of sec. 18 the phosphate bed was found to have a thickness of 66 inches and an average content of 33.96 per cent phosphorus pentoxide (P_2O_5) equivalent to 74.19 per cent tricalcium phosphate ($Ca_3(PO_4)_2$). In the NE. ¼ SE. ¼ sec. 36 in this township the prospect made by the Survey party showed the phosphate bed to be 73 inches thick with an average content of 34.37 per cent phosphorus pentoxide, equivalent to 74.5 per cent tricalcium phosphate. (See pp. 82, 87.) The weight of such rock from previous determination is about 180 pounds per cubic foot. On the assumption that the lower thickness is the average for the area, it is estimated that this township contains as a minimum 148,008,900 long tons of high-grade phosphate rock, at a depth of 5,000 feet or less. The estimate assumes that the rocks are horizontal. The rocks are, however, inclined at different angles, so that the estimate should fall somewhat below the actual content of the phosphate beds. In view of the complex structure of the township it seems wise to leave this difference as an additional margin of safety for the estimate given.

UTILIZATION OF THE LAND.

The alluvial meadows can be irrigated and farmed, and some of the lower benches can doubtless be dry-farmed. The higher ground affords pasturage. The township as a whole is being utilized at present to some extent for cattle grazing, and outside the reservation line for sheep grazing.

T. 6 S., R. 38 E.

TRANSPORTATION FACILITIES.

The nearest railroad point to T. 6 S., R. 38 E., is Bancroft, on the Oregon Short Line Railroad, 12 to 15 miles south. A stage line runs from that point to Chesterfield, about 3 miles southeast of the reservation. An excellent road connects this township with Chesterfield and Bancroft.

GEOLOGY.

The geologic features of the portion of the township included in the reservation are shown on the general map (Pl. III).

The greater part of the district examined is occupied by the broad valley of Portneuf River, and its alluvial meadows and older

sloping bench lands are underlain by Tertiary and Quaternary deposits.

The older rocks exposed in the west half of the district are all of Cambrian and Ordovician age and are folded and probably faulted as well, though the details of the structural features have not been worked out. A broad patch of Swan Peak quartzite (Ordovician) overlies different members of the Cambrian in secs. 6 and 7 in a fault that is interpreted as a part of the Putnam thrust. (See pp. 62–65.)

East of Portneuf River in secs. 1 and 12 Carboniferous rocks of the Wells formation appear. Between these rocks and the Cambrian and Ordovician rocks west of the river it seems probable that a fault intervenes, but its position is concealed by the thick cover of later sediments that occupy the valley. In secs. 32 and 33, T. 5 S., R. 38 E., the Cambrian and Ordovician rocks are faulted against the Rex chert member of the Phosphoria. Numerous other faults occur in that township, so that faults may reasonably be expected in the region between the older and younger Paleozoic rocks of this township.

PHOSPHATE DEPOSITS.

In the SE. ¼ sec. 35, T. 5 S., R. 38 E., the Phosphoria formation advances southwest toward this township but passes beneath the Tertiary cover a short distance north of the township line. Float of phosphate is abundant near the north quarter corner of sec. 2. It seems probable then that phosphate rock enters the NW. ¼ NE. ¼ sec. 2 beneath the cover, but its course and extent beneath the cover can not be determined from present data. The probability of faulting renders unlikely any considerable continuation of the Phosphoria formation in this township. For this reason no estimates of possible phosphate deposits are presented for this township. It may be noted, however, that the phosphate in sec. 36, T. 5 S., R. 38 E., shows a thickness of 73 inches without partings and an average content of 34.37 per cent phosphorus pentoxide, equivalent to 74.5 per cent tricalcium phosphate. A description of the phosphate beds there exposed is given on page 103.

UTILIZATION OF THE LAND.

Much of the bottom and bench land can be irrigated and farmed or dry-farmed. Hay, oats, and potatoes are raised at Faulkner's ranch, in secs. 3 and 4. The hills to the north, east, and west afford pasturage and some timber.

MINERAL RESOURCES.

PHOSPHATE DEPOSITS.

GENERAL SUMMARY OF TONNAGE ESTIMATES.

The tonnage estimates in the preceding township descriptions include only the figures for the areas examined in detail in 1913. Although approximate, they relate only to the main bed, which lies near the base of the phosphate shales, and thus exclude some workable high-grade rock and much lower grade rock that may eventually become workable. Several areas of considerable size that may contain valuable phosphate deposits at workable depths are also excluded because they are covered with late deposits which conceal the underlying structure to such an extent as to make hazardous any estimate of the phosphate content. The estimates are based on the best data available and are believed to be conservative.

Estimates of phosphate rock available in the townships considered in this report.

	Long tons.
T. 3 S., R. 37 E	94,925,800
T. 4 S., R. 37 E	204,977,800
T. 5 S., R. 37 E	55,744,200
T. 4 S., R. 38 E	234,870,000
T. 5 S., R. 38 E	148,008,900
	738,526,700

Estimates for the western field.

	Long tons.
Total for area examined in 1913	738,526,700
Total for area examined in 1912 [74]	1,889,480,200
Total for area examined in 1911	1,347,370,000
Total for area examined in 1910	1,158,970,000
Total for area examined in 1909, minus 90,000,000 tons estimated for Georgetown district, which is duplicated in total for 1911	156,950,000
	5,290,296,900

Stone and Bonine[75] report for the Elliston field, Mont., 86,000,000 short tons (equivalent approximately to 76,785,700 long tons), and Pardee[76] reports for the Garrison and Philipsburg fields, Mont., a total of 97,000,000 long tons. These amounts added to the amounts previously tabulated make a total of approximately 5,464,082,000 long tons.

[74] Report in preparation.

[75] Stone, R. W., and Bonine, C. A., The Elliston phosphate field, Mont.: U. S. Geol. Survey Bull. 580, p. 383, 1914.

[76] Pardee, J. T., The Garrison and Philipsburg phosphate fields, Mont.: U. S. Geol. Survey Bull. 640, p. 223, 1917.

Additional areas have been examined in detail in Idaho, Wyoming, and Utah since 1913, for which estimates are not yet available, and considerable portions of the reserve yet remain to be surveyed. Thus it appears that the figures given will eventually be greatly increased.

UTILIZATION OF WESTERN PHOSPHATE.

At present the western phosphate is but little utilized, although its chemical and physical constitution would make relatively easy its manufacture into superphosphates by the mixture of about equal parts of ground rock and sulphuric acid. The demand for fertilizers in the Pacific coast district is moderate and is readily met by the companies now in operation. The future development of the deposits depends in large measure upon the growth of the demand for fertilizers in the Central and Eastern States and upon the adoption of some method of manufacture which will enable the producers to deliver the phosphoric acid in concentrated form, so that the high cost of transportation may be offset. The manufacture of "high-grade" superphosphates as a means to this end has been discussed by Gale in a previous report.[77] Several processes for making soluble phosphates have also been reviewed by Phalen.[78]

In spite of the present small demand for this rock there can be no doubt that the growing recognition in this country of the importance of the proper use of fertilizers will sooner or later make this western phosphate field the scene of one of the Nation's most important industries.

The situation of the deposits of the Fort Hall Indian Reservation with respect to existing railways is less favorable than that of the phosphate beds near Sage and Cokeville, Wyo.; Montpelier, Paris, and Georgetown, Idaho, and the Elliston and other fields in Montana. Favorable grades, however, exist in the valleys of the upper Portneuf River and of Ross Fork Creek for spur tracks from the Oregon Short Line Railroad. These spurs would bring shipping facilities within short hauling distances of the deposits.

DEVELOPMENT AND PRODUCTION.

The true nature of the phosphate rock seems first to have been recognized in 1889 in Cache County, Utah.[79] Beds of phosphate were also independently discovered in 1897 in Rich County, Utah,[80] but it

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[77] Gale, H. S., U. S. Geol. Survey Bull. 470, pp. 449–451, 1911.

[78] Phalen, W. C., Phosphate rock: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, pp. 239–242, 1916.

[79] Richter, A., Western phosphate discovery: Mines and Methods, vol. 2, p. 207, 1911.

[80] Jones, C. C., The discovery and opening of a new phosphate field in the United States: Am. Inst. Min. Eng. Trans., vol. 47, pp. 192–216, 1914.

was not until about 1904 that any systematic exploration or development of them took place.

Three companies soon entered the field, and in 1906 shipping was begun from Montpelier, Idaho, and Cokeville and Sage, Wyo. The known deposits at that time were grouped in scattered localities within a comparatively few miles of the junction point of the three States, Idaho, Wyoming, and Utah. In 1909 the Geological Survey began the detailed examinations, which with some interruptions have been continued since and are still far from completion. These examinations have shown the area underlain by phosphate to be far greater than was at first supposed and have revealed the presence of enormous bodies of high-grade rock. Unfortunately, the companies engaged in mining the rock became involved in litigation concerning the legality of their locations. This litigation, together with the long distance from available markets and high cost of transportation, has prevented any extensive exploitation of the deposits. By 1916 five companies were represented in the field, but only two of them were active at that time and production was very small. In 1917 the waning industry experienced a sharp recovery, and four companies, one of them new, were operating. There was also a general improvement in market conditions, which, if maintained, may result in more extended development of the deposits.

Although the field is the largest within the United States, and, as far as known, the largest in the world, production has thus far been small because of the adverse conditions. From the beginning, in 1906, when figures first became available, until 1918 the total production amounted to 91,992 tons for the entire field, an average of only 7,076 tons annually for the 13-year period. A maximum of production appears to have been reached in 1912, when it amounted to 11,612 long tons, valued at $49,241.[81] From that time the quantity marketed grew smaller, until in 1916 it was 1,703 tons, valued at $5,350, and represented only about 0.08 per cent of the total for the entire country.[82] In 1917 under the revived demand the output was 15,096 long tons, valued at $41,756, an increase in production of 786 per cent compared with 1916.[83] The average price per ton was $2.77, which was 37 cents per ton less than in the preceding year.

The impetus given by the war to agriculture leads directly to larger utilization of phosphate rock and its derivatives as fertilizer. As the beneficial effects of the application of the phosphates to the

[81] Phalen, W. C., Phosphate rock: U. S. Geol. Survey Mineral Resources, 1913, pt. 2, pp. 276–277, 1914.

[82] Stone, R. W., Phosphate rock: U. S. Geol. Survey Mineral Resources, 1916, pt. 2, p. 32, 1918.

[83] Idem, 1917, pt. 2, p. 11, 1918.

soil become more generally realized, the demand for the rock should be permanent and increasing.

STATUS OF WESTERN PHOSPHATE LANDS.

In Utah, Idaho, Wyoming, and Montana the great bulk of the deposit is on public lands, though some has passed into private hands. The public lands are withdrawn from entry pending examination and classification. Agricultural entry on these lands is permitted, but mineral rights are reserved by the Government. No estimates of the acreage of phosphate land in private ownership are available, but the acreage of the outstanding withdrawals of public land in the States named is shown below:

Outstanding phosphate withdrawals, July 1, 1918.

	Acres.
Utah	302, 465
Idaho	1, 015, 717
Wyoming	998, 592
Montana	287, 883
	2, 604, 657

In addition to the above areas 4,080 acres in the Fort Hall Indian Reservation, Idaho, and 20,576 acres in the Wind River Indian Reservation, Wyo., have been examined in detail, formally classified as phosphate land, and restored for entry. In all there are 2,629,313 acres of public land which will ultimately be available for entry and exploitation in addition to the lands privately owned.

ORIGIN OF THE DEPOSITS.

The origin of the western phosphate deposits has an important commercial bearing, for if they were residual, like those of the brown rock of Tennessee, or of secondary origin, they might be expected to pass at comparatively shallow depths into unleached low-grade phosphate or even into phosphatic limestones. Thus the valuable deposits would be limited to a comparatively short distance from the outcrop, and the great body of rock under cover in the synclines would be valueless. Absolute certainty on this point probably can not be reached without deep drilling. On the other hand, the phosphate beds have been observed in many parts of the region and under many conditions by a number of geologists, and everywhere they appear to be true bedded deposits, analogous to coal or limestone, and retain their thickness and quality over wide areas. r these reasons they are regarded as original sedimentary de-'ts, and it is considered probable that they maintain in depth

the characteristics displayed at the surface. Upon this assumption rest the estimates given for the western field.

The sources of the phosphoric acid and the methods of its accumulation are to a considerable degree subjects of speculation, but it will perhaps be helpful to summarize opinions thus far advanced and to indicate the probable direction of solution of the problems involved.

The first detailed accounts of the western phosphates are contained in papers of Gale and Richards [84] and Blackwelder.[85] These authors regard the phosphates as original marine sedimentary deposits, and Gale and Richards give a very brief summary of the hitherto recognized sources of phosphorus and the method of its accumulation as phosphates [86] through the agency of organic and physicochemical processes.

Because of the relative scarcity of organic remains in the actual phosphate beds Richards and Mansfield [87] were inclined to place greater emphasis on physicochemical than on organic sources and agencies.

Blackwelder has contributed two important later papers. In the first [88] he gives an interesting suggestive account of the cycle of changes undergone by phosphorus from its mineral form in apatite through solution, assimilation by plants or animals, deposition on the sea bottom or on land, accumulation into deposits, burial, deformation, and metamorphism back to apatite again. Many subcycles are included, and individual atoms of phosphorus may have had widely different histories. In the second [89] he gives in abbreviated form as derived from available literature a view of organic accumulation, which is substantially repeated here for reference. In the ocean special conditions of currents and temperature, together with other factors not yet understood, may have induced the wholesale killing of animals over large areas and the accumulation of putrefying matter on the sea floor in moderate and shallow depths. Decomposition through the agency of bacteria produced ammoniacal solutions, which dissolved the solid calcium phosphate in bones, teeth, brachiopod shells, and tissues. The abundance of putrefac-

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[84] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

[85] Blackwelder, Eliot, Phosphate deposits east of Ogden, Utah: U. S. Geol. Survey Bull. 430, pp. 536–551, 1910.

[86] Gale, H. S., and Richards, R. W., op. cit., pp. 461–462.

[87] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 376–377, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, p. 74, 1914.

[88] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, pp. 285–298, 1916.

[89] Blackwelder, Eliot, Origin of the Rocky Mountain phosphate deposits: Geol. Soc. America Bull., vol. 26, pp. 100–101, 1915. (Abstract.)

tive material also prevented the existence of organisms attached to the bottom, and most calcareous shells descending from the surface were probably dissolved by the abundant carbonic acid arising from decay. For physicochemical reasons, already partly understood, the phosphatic material was quickly redeposited in the form of hydrous calcium carbophosphates, locally filling, incrusting, and replacing shells, teeth, bones, and other material, but especially forming small rounded granules of colophanite and finally a phosphatic cement among all particles. The granular texture is ascribed chiefly to physicochemical conditions, such as result in the formation of oolitic greenalite, limonite, aragonite, and similar minerals. After having been formed in quiet water some of the granules were reached by bottom-scouring currents and incorporated in clastic deposits and in some places were strewn over eroded rock surfaces and so became constituents of basal conglomerates.

The latest contributor to the discussion of the origin of the western phosphates is Pardee,[90] who is inclined to look with disfavor upon the view that unusual or abundant sources supplied phosphates rapidly to the sea. He points to the existence of glacial conditions elsewhere in Permian time and suggests that cool temperatures may have prevailed during the deposition of the western phosphates. Carbon dioxide (CO_2) is retained most abundantly by waters of low temperature, and this gas is supplied not only from atmospheric sources but also from organic substances that decompose in sea water or on the sea floor. Conditions would thus be unfavorable for the growth of coralline limestone or for the chemical precipitation of lime. Moreover, in such waters limy objects would tend to be dissolved and the formation of limestones composed of shells and skeletons of marine organisms would be hindered. Therefore, on the assumption that the precipitation of phosphate was not checked, that material would accumulate in relatively pure form. The great volume of the deposit (see the estimates of tonnage, p. 105) needs no further explanation than the continued or extensive application of the process that initiated the formation of the phosphate.

The western phosphates are agreed by all who have seen them in the field to be original marine deposits, analogous to those of Tunis, Algeria, England,[91] and Egypt, and to the blue phosphate of Tennessee. The physiographic conditions of their deposition are little known, but there are at least six lines of evidence which throw light upon the problem and from which it may be possible to deduce a working hypothesis.

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[90] Pardee, J. T., The Garrison and Philipsburg phosphate fields, Mont.: U. S. Geol. Survey Bull. 640, pp. 225–228, 1917.

[91] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, 94, 1916.

1. The fauna, according to Girty,[92] is quite different from the Carboniferous faunas of the Mississippi Valley and even among western faunas has an extremely individual and novel facies. Thus the area of deposition, though of great extent, must have been separated or nearly so from the main ocean.

2. Analyses of higher-grade phosphate rock, like that which constitutes the main bed, show generally less than 12 per cent of SiO_2, Al_2O_3, Fe_2O_3, and MgO, all added together.[93] Silica forms the greater part of this amount, and some of it may be of organic origin. It thus appears that detrital material from the land is largely absent from the deposit. This condition may be explained in several ways: The deposit may have been laid down in relatively deep water, like some of the modern oozes; or the water of deposition, though shallow, may have been too far from land to receive much detritus from that source; or the lands adjacent to the waters of deposition may have been so low, through base-leveling or otherwise, that they furnished little clastic material to the sea; or, according to an earlier suggestion of Hayes,[94] strong marine currents may have swept away the fine terrigenous material, leaving only the phosphatic oolites. The physiographic conditions changed from time to time during the deposition of the phosphatic shales, for beds of shale, sandstone, and limestone, some of which are more or less phosphatic, are interbedded with the more nearly pure phosphate.

3. The period of deposition may have been long. The time required for the deposition of the phosphate beds and the accompanying Permian strata is not known, but some data permit suggestive comparisons. Though there is at least local unconformity at the base of the Phosphoria formation, this is not regarded as indicating any great time interval. The top of the formation may also be marked by an unconformity, and the faunal change above is very pronounced. The time interval here may be large, but, on the other hand, the faunal change may have been produced by the geographic changes of the late Permian or early Mesozoic without greater lapse of time here than elsewhere. The phosphatic shales, with which are grouped some nonphosphatic or lean shales, sandstones, and limestones, are about 150 feet thick, and of this thickness the actual beds of phosphate rock form only a small proportion. The Phosphoria formation as a whole, representing all the known Permian of the region, is about 500 feet thick. The Permian section in Kansas,

[92] Girty, G. H., The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah: U. S. Geol. Survey Bull. 436, p. 8, 1910.
[93] Gale, H. S., and Richards, R. W., op. cit., p. 465.
[94] Hayes, C. W., Tennessee phosphates: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 534, 1896.

according to Prosser,[95] is about 2,000 feet thick; in Texas the Permian formations are reported to be 5,000 feet thick[96] and in Oklahoma 2,600 feet thick.[97] If these deposits may be regarded as having been laid down during time intervals at all similar, it is obvious that the deposition of the Phosphoria formation of Idaho was at a much slower rate than the accumulation of Permian strata in the regions named farther east. It seems at least reasonable, therefore, to attribute the thickness and richness of the phosphatic strata to long-continued slow deposition under conditions which excluded for considerable intervals the accumulation of terrigenous material and of carbonate of lime.

4. The ordinary processes of bacterial decay give rise to ammonium phosphate, which, according to Clarke,[98] has been experimentally shown to react upon mineral substances in such manner as to produce phosphates resembling those actually found. Blackwelder[99] states that such experiments have been carried out by several investigators and that the conditions are such as may readily occur on the sea bottom where organic decomposition is in progress. Thus calcareous shells become phosphatized, and even such organic material as excretory pellets and bits of wood is known to have been altered in the same way. Bones, which initially contained about 58 per cent of tricalcium phosphate, have their organic matter replaced by phosphatic minerals, thus raising the ratio to 85 per cent or more.

5. The oolitic texture so characteristic of much of the western phosphate is doubtless closely connected with the origin of the rock. In a well-presented discussion of the origin of oolites Brown[1] concludes that the older oolitic beds of Pennsylvania were probably all originally laid down as beds of calcareous oolites composed of the mineral aragonite. As this mineral is unstable under ordinary conditions of the formation of rocks it soon began to change. Where solutions carrying other substances, such as silica or iron, were present the oolites were more or less completely replaced—for example, the siliceous oolites or the Clinton ore.

6. Calcareous oolites are now forming at a number of places, notably in the region of the Florida Keys and the Bahamas, where

[95] Prosser, C. S., Revised classification of the upper Paleozoic formations of Kansas: Jour. Geology, vol. 10, pp. 703–737, 1902.

[96] Cummins, W. F., Report on the geology of northwestern Texas: Texas Geol. Survey Second Ann. Rept., p. 398, 1891.

[97] Beede, J. W., Invertebrate paleontology of the upper Permian red beds of Oklahoma and the Panhandle of Texas: Kansas Univ. Sci. Bull., vol. 4, No. 3, p. 136, 1907.

[98] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, p. 523, 1916.

[99] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, p. 294, 1916.

[1] Brown, T. C., Origin of oolites and the oolitic texture in rocks: Geol. Soc. America Bull., vol. 25, pp. 745–780, pls. 26–28, 1914.

they have been studied by Drew[2] and Vaughan.[3] Drew has shown that in these regions denitrifying bacteria are very active and are precipitating enormous quantities of calcium carbonate largely in the form of aragonite. Vaughan shows that this chemically precipitated calcium carbonate forms spherulites or small balls, which, by accretion, may become oolitic grains of the usual size, or it may accumulate around a variety of nuclei to build such grains. He reaches the conclusion that all marine oolites originally composed of calcium carbonate, of whatever geologic age, may confidently be attributed to this process. Drew's studies of the distribution of denitrifying bacteria have shown them to be most prevalent in the shoal waters of the Tropics. In combining the results of Drew and Murray, Vaughan considers that great limestone formations, whether composed of organic or chemically precipitated calcium carbonate, were laid down in waters of which at least the surface temperatures were warm if not actually tropical.

Among the deductions from the preceding data, which may serve as a partial tentative working hypothesis for the origin of the western phosphates, may be mentioned the following:

1. The phosphatic oolites and their matrix were probably deposited originally as carbonate of lime in the form of aragonite.

2. The waters were probably shoal and of warm or moderate rather than of cold temperature.

3. The lands that bordered the depositional area were low and furnished little sediment to the sea. Thus far the supposed depositional conditions agree with known modern conditions in the Florida region.

4. The phosphatization of the oolitic deposit was probably subsequent to its deposition rather than coincident with it, for Drew shows that the activities of denitrifying bacteria reduce the nitrate content of the sea water and hence the growth of marine plants and of animals dependent upon them. Such conditions are favorable for the deposition of the carbonate but not of the phosphate of lime.

5. Cooler temperature in the waters of deposition, perhaps induced by changes in the character or direction of marine currents, checked the activities of the denitrifying bacteria and hence the conditions favorable for the formation of oolitic limestone. At the same time plant and animal life increased in the waters and furnished the decaying matter necessary for the phosphatization of the oolitic lime-

[2] Drew, G. H., On the precipitation of calcium carbonate in the sea by marine bacteria, and on the action of denitrifying bacteria in tropical and temperate seas: Carnegie Inst. Washington Pub. 182, Papers from the Tortugas Laboratory, vol. 5, pp. 9–53, 1914.

[3] Vaughan, T. W., Preliminary remarks on the geology of the Bahamas, with special reference to the origin of the Bahaman and Floridian oolites: Carnegie Inst. Washington Pub. 182, Papers from the Tortugas Laboratory, vol. 5, pp. 47–54, 1914.

stone in the general manner set forth in Blackwelder's account given above. Perhaps Pardee's idea of glacial climate may have a bearing in this connection.

6. The temperature change may have been sufficiently abrupt to cause the death of multitudes of certain marine animals, as suggested in Blackwelder's account. This material would be sufficient to produce a fairly rapid phosphatization of the oolitic limestone. Such an assumption, however, is not compulsory, because the phosphatic shales as a whole were doubtless formed slowly, and there was time for sufficient accumulation and trituration of organic remains to produce the observed phosphatization before the moderate crustal changes that permitted the introduction of the clastic material which buried the phosphate bed.

7. The conditions set forth above, which were outlined particularly with reference to the main phosphate bed, probably were repeated on a less extensive scale for the lesser beds. Shaly partings or minor shale beds in the phosphate might be the result of local seaward drift of land-derived silts after some unusual or protracted storm.

8. The sea in which the phosphate was deposited was closed on the east, south, and west but may have had connections with the ocean northward and northwestward, for Girty[4] notes faunal resemblances that are traceable into Alaska, Asia, and eastern Europe, and Adams and Dick[5] report the discovery of phosphate at apparently the same horizon in Alberta.

COAL PROSPECTS.

Two prospects for coal have been opened by the Indians in T. 7 S., R. 33 E. One of these prospects is in the NW. ¼ SW. ¼ sec. 23 and the other in the SW. ¼ SW. ¼ sec. 15. The prospect in sec. 23 was opened in carbonaceous plant-bearing shales associated with the Tertiary rocks. Specimens of these plant remains were collected and submitted to F. H. Knowlton, of the Survey, for identification, but they proved to be fragments of bark and stems that were not determinable. There are two small pits about 20 feet apart, each exposing about 2½ feet of beds. The rock is too shaly to be of value for coal.

The prospect in sec. 15 is opened in a small, nearly vertical dike of obsidian or black volcanic glass that is intruded between basalt and white volcanic ash. The ash is here baked and discolored brown. This prospect is locally called the Smut mine. There are three small pits on a low knoll just north of the high basalt hills, east of Bannock Valley. Several tons of the basalt have been removed in the process of making the openings.

[4] Girty, G. H., op. cit., p. 9.

[5] Adams, F. D., and Dick, W. J., Discovery of phosphate of lime in the Rocky Mountains: Canada Commission of Conservation, Ottawa, 1915.

METALLIFEROUS DEPOSITS.

Prospects.—In the saddle south of Bannock Peak, near the center of sec. 34, T. 9 S., R. 32 E., an old abandoned shaft and a dump were found. The material on the dump was highly ferruginous but showed no valuable minerals. A similar ferruginous zone, not prospected, was found on the ridge in the SE. ¼ SE. ¼ sec. 25 that leads to the high rocky hill to the northeast. At this locality there were large float fragments 2½ to 3 feet thick of highly ferruginous material. The actual vein was not seen. An assay of a sample of this material showed only a faint trace of gold.

Gold placers.—The Fort Hall Indian Reservation includes along Snake River some placer deposits of fine gold that have been locally prospected and worked in the region of the Fort Hall bottoms. Horse Island, which lies just outside the reservation and is really a continuation of the Fort Hall bottoms, also contains placers that have been worked. These deposits have been described by Hill,[a] from whose account the following statement is compiled.

The bottoms have an average elevation of 8 to 10 feet above the normal water level of Snake River. Water stands 2 feet below the surface at the north end of the bottoms and 9 feet below at the south end.

Gray to black sandy loam that locally contains considerable clay forms most of the surface material, but gravels occur at a few places, irregularly distributed over the bottoms. In general, the gravel bars do not cover much more than an acre, but here and there they cover several acres. The bars are more numerous and larger nearer the river.

There is no doubt that gravels similar to those along the present channel of Snake River underlie all the Fort Hall bottoms. The sandy loam extends from 2 feet to 12 feet below the surface.

From the distribution of the gravels it is thought that they represent the tops of buried bars, such as are now found along the present channel of the Snake, and from analogy it is thought that the rich gravels are of rather small extent, corresponding to the skim-bar gravels of the present stream.

Bedrock was not found in the Fort Hall bottoms. Basalt forms the west bank of the river at several places but does not occur east of the river. Similar gravels overlie partly consolidated clayey sand in the terrace east of the bottoms, and these may prove to be the bedrock of the bottoms. Lava 10 feet thick, which has a strong westerly dip, was encountered at a depth of 75 feet in a well in the vicinity of the Fort Hall Agency. On account of its pronounced

[a] Hill, J. M., Notes on the fine gold of Snake River, Idaho: U. S. Geol. Survey Bull. 620, pp. 271–294, 1915.

westerly dip it would probably be found at considerable depth if it extended under the bottoms.

The gravels of the Fort Hall bottoms average less than 1 cent to the yard in gold. The skim-bar gravels, which have been worked each year after high water, carry at least 65 cents a yard in fine gold and perhaps as much as $2 to $3 a yard. The skim bars, however, form a minor part of the total amount of the gravels of the Fort Hall bottoms.

Considerable placer mining has been done in the past on Horse Island, but of late the gravels have received little attention. The surface of the island is 6 to 10 feet above the normal water level of Snake River, and conditions are generally similar to those of the Fort Hall bottoms.

Rockers were used in working most of these gravels, though some on the Elliott ground at the north end of the island were worked with a "machine." Horse-drawn scrapers were used to remove the soil and at the machine settings to bring the gravels from the pit to the sluice.

Apparently the pay gravels follow more or less well-defined lines or bars, which have a somewhat crescentric shape and are the tops of old high-water bars like those that are deposited in the present stream channel.

Fort Hall mining district.—In the vicinity of Pocatello, south of the reservation, there are a number of metalliferous prospects which comprise what has been called the Fort Hall mining district. This region has been described by Weeks and Heikes[7] and by Bell.[8]

The following notes are furnished by E. L. Jones, jr., who examined the ore deposits of the Fort Hall district in September, 1916, for data to be incorporated in a general report on the ore deposits of the State. There are numerous prospects in the Fort Hall district, but only two of them have produced small quantities of ore—the Moonlight of the Pocatello Gold & Copper Mining Co., 9 miles northeast of Pocatello, and the Fort Hall Mining Co., 8 miles southeast of Pocatello. From the Moonlight mine two carloads of ore were shipped in 1904, and in 1916 a shipment of 9 tons, which had an average content of 22 per cent copper, 8.3 ounces silver, and 0.005 ounce gold to the ton, was sorted from the dumps. The deposits are small irregular replacements along fractures in a conglomeratic shale of Ordovician (?) age. Underlying the conglomeratic shale and intercalated with other shale beds there are masses of schistose gray and green igneous rocks that are probably altered disabase. The ore is mainly chalcopyrite, which is replaced near the surface by secondary minerals—chalcocite, bornite, and malachite. The Fort

[7] Weeks, F. B., and Heikes, V. C., Notes on the Fort Hall mining district, Idaho: U. S. Geol. Survey Bull. 340, pp. 175–183, 1908.

[8] Bell, R. N., Reports of the Idaho State Inspector of Mines, 1906–1912.

A. CHARACTERISTIC EXPOSURE OF VOLCANIC ASH IN SEC. 11, T. 4 S., R. 36 E.

B. EXPOSURE AND WIND SCULPTURE OF VOLCANIC ASH ON STARLIGHT CREEK, T. 8 S., R. 33 E.

Hall mine is opened by 8,000 feet of tunnels and drifts which cut conglomerate, shale, sandstone, quartzite, and limestone beds of Ordovician (?) age. The ore occurs as veins and seams in a sharply folded limestone bed, and it is composed of chalcopyrite, pyrite, and subordinate galena in a calcite and quartz gangue. Two carloads of ore have been shipped from the property, the last one in 1916.

VOLCANIC ASH.

In different localities in the reservation, including parts of Tps. 7, 8, and 9 S., R. 32 E.; Tps. 6, 7, 8, and 9 S., R. 33 E.; Tps. 4 and 5 S., R. 35 E.; Tps. 3 and 4 S., R. 36 E., and probably other townships, there are extensive deposits of white volcanic ash included in the Tertiary rocks. In some exposures beds 30 to 50 feet thick have been observed. (See Pl. XI.) With the kind assistance of H. G. Ferguson the writer examined under the microscope some of the material of better grade. It contained very little extraneous matter and consisted largely of tiny fragments of volcanic glass and some glassy feldspar. The fragments of glass contain tiny tubes and vesicles and some crystallites. The ash is mostly consolidated into beds that break into easily friable pieces.

A characteristic sample of the better material, when crumbled between the fingers, all passed through a 40-mesh screen and about three-fourths of the sample passed through a 100-mesh screen, forming a fine white flour.

The material resembles the ash of Nebraska as described by Merrill,[9] Barbour,[10] and others and also resembles material collected by Peale in Idaho and Montana and described by Merrill.[11] Some of the samples thus described were taken by Peale from Marsh Creek and the Portneuf Canyon, regions adjacent to the Fort Hall Indian Reservation. Merrill gives the following analysis of the sample from Portneuf Canyon:

Analysis of sample of volcanic ash from Portneuf Canyon, Idaho.[12]

Ignition	6.00
Water	1.60
Fe_2O_3 and Al_2O_3	16.22
SiO_2	68.92
CaO	1.62
MgO	Trace.
Na_2O	1.56
K_2O	4.00
	99.92

[9] Merrill, G. P., U. S. Nat. Mus. Proc., vol. 8, p. 99, 1885.

[10] Barbour, E. H., The deposits of volcanic ash in Nebraska: Ann. Rept. Nebraska State Board Agr., 1896.

[11] Merrill, G. P., Notes on the composition of certain "Pliocene sandstones" fr Montana and Idaho: Am. Jour. Sci., 3d ser., vol. 32, pp. 199–204, 1886.

[12] Merrill, G. P., idem, pp. 201–202.

The sample yielded water readily in the closed tube and fused readily with swelling before the blowpipe. Many of the fragments contained bubbles and tubelike cavities.

The Nebraska ash finds many uses. Under the name "pumice" it is used in scouring and polishing preparations. Similar uses may some day be found for the abundant ash deposits of the reservation.

SOILS.

The soil of the Fort Hall bottoms, which is composed of recent alluvium, is mostly a fine light-grayish clayey soil with an intermixture of a small amount of fine sand. It is very calcareous and readily effervesces with dilute hydrochloric acid. Qualitative tests show no water-soluble carbonates and slight traces, if any, of sulphates and chlorides. Frémont, in his exploring expedition of 1843–44, collected a sample of the soil from the river bottom near Fort Hall, which was then a trading post of the Hudson Bay Co., on Portneuf River, about 9 miles above the mouth. He gives the following analysis of the sample:[18]

Analysis of soil in river bottom near Fort Hall.

Silica	68.55
Alumina	7.45
Carbonate of line	8.51
Carbonate of magnesia	5.09
Oxide of iron	1.40
Organic vegetable matter	4.74
Water and loss	4.26
	100.00

In some places the soil is more sandy and locally gravels appear. The moister areas are overgrown with rushes and other marsh plants. The drier meadows are utilized chiefly for their wild hay.

The Gibson terrace, which is composed of the older alluvium, has a more sandy soil and more gravels are exposed at the surface. The soil appears to be chemically similar to that of the Fort Hall bottoms below. This flat is farmed and yields excellent crops of potatoes, alfalfa, and some grain outside the reservation, where water is available for irrigation. It is also being farmed to some extent within the reservation.

Where the volcanic sand overlies the surface in more than mere thin patches the soil is coarse, incoherent, and of little value for agriculture.

[18] Frémont, J. C., Narrative of the exploring expedition to the Rocky Mountains in the *year 1842 and to Oregon* and north California in the years 1843–44, p. 164, London, *1846.*

The soils of the sloping bench lands are relatively fine and calcareous, suitable in many places for dry farming and in the lower areas capable of irrigation.

WATER RESOURCES OF THE FORT HALL INDIAN RESERVATION.

By W. B. Heroy.

FIELD WORK AND ACKNOWLEDGMENTS.

In order to make this report cover with some degree of fullness the natural resources of the Fort Hall Indian Reservation the writer was requested to prepare a discussion of the water supply. Accordingly, a short period in the fall of 1914 was spent in the field in obtaining data, chiefly with reference to underground waters. The statements made regarding wells and the occurrence of ground water on the reservation rest on the information obtained at that time. (See Pl. XIII, p. 133.)

The records of stream flow have been obtained from the records of the United States Geological Survey. The discussion of water power is largely based upon an unpublished report by E. C. La Rue, hydraulic engineer of the United States Geological Survey. Data concerning the Fort Hall irrigation project were in the main obtained from a report by R. J. Ward, of the Indian Irrigation Service, which was courteously lent by W. M. Reed, chief engineer of the service.

SURFACE WATER.

SNAKE RIVER BASIN.

The Fort Hall Indian Reservation lies entirely within the area drained by Snake River and its tributaries, although the extreme south end of the reservation is but a short distance from the divide between the Snake River and Bear River basins.

Snake River forms the northwest boundary of the reservation for a distance of about 25 miles from the mouth of Blackfoot River to that of Portneuf River. Throughout this portion of its course the Snake flows in general through a broad alluvial valley, though its northwest bank is here and there bordered by cliffs which mark the easternmost extension of the Snake River lava. The channel of the river is in most places only a few feet below the level of the valley, but in some places steep gravel banks 15 feet high have been cut on the outside of bends. The gradient, which is only about 2½ feet to the mile, is not uniformly distributed, and the course of the river is

broken into rapids and reaches. The large volume of water carried at ordinary stages results in a swift current over the rapids. Consequently the river is not navigable, except for small boats or canoes, and then only with the current.

In volume of flow and drainage area Snake River ranks among the great rivers of the United States. Its headwaters rise in the Continental Divide along the greater part of the east boundary of Idaho and across part of western Wyoming. Originally it was called the Lewis Fork of Columbia River, after the explorer, but it takes its present name from the Shoshones, or Snake Indians, many of whom now have their homes in the Fort Hall Reservation. The main stream, which rises in the southern part of Yellowstone National Park, flows southward through Jackson Valley in Wyoming and then turns westward into Idaho. Most of its course in eastern Idaho is through a deep canyon, from which it emerges a few miles east of Idaho Falls. Here it is joined by Henrys Fork, a large tributary which has its origin in Henrys Lake, in the extreme northeast corner of southern Idaho.

In view of the importance of Snake River to southern Idaho, both for irrigation and for power, much care has been exercised in determining the volume of water which it carries. A number of gaging stations have been established by the United States Geological Survey, in part in cooperation with the State of Idaho and with other governmental agencies, for measuring the flow of the river. One of these stations was established on June 6, 1910, in sec. 31, T. 3 S., R. 34 E. Boise meridian, about 10 miles southwest of Blackfoot and about a quarter of a mile below the mouth of Blackfoot River. The measurements at this station, which is located in part on the reservation, indicate the amount of water which enters that part of Snake River which forms the west border of the reservation. The flow of the river at this station is affected both by the irrigation diversions above and by water released from storage, so that it does not represent the normal volume of the river The observations made at this station have been published in detail in other reports of the United States Geological Survey,[14] and only a summary of the results obtained is given here. The following table gives the flow of Snake River at this station for the period of record:

[14] U. S. Geol. Survey Water-Supply Papers 292, pp. 295–297, 1913; 312, pp. 270, 271, 1915; 332, pp. 285–287, 1916.

Monthly discharge of Snake River near Blackfoot, Idaho, for 1910–1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1910.				
June 6-30	17,100	3,560	8,250	409,000
July	9,510	890	3,960	243,000
August	1,050	238	469	28,800
September	1,920	1,120	1,540	91,600
The period				772,400
1910–11.				
October	2,900	1,570	2,430	149,000
November	3,780	2,900	3,410	203,000
December	3,870	2,270	3,230	199,000
January	5,870	2,140	3,250	200,000
February	7,270	2,270	3,870	215,000
March	5,620	2,200	4,000	246,000
April	9,450	3,610	4,960	295,000
May	18,800	9,170	14,800	910,000
June	32,900	14,800	25,600	1,520,000
July	21,900	1,300	9,200	566,000
August	6,860	625	3,520	216,000
September	3,700	2,520	3,150	187,000
The year	32,900	625	6,780	4,910,000
1911–12.				
October	4,120	2,680	3,650	224,000
November	4,850	2,410	3,850	229,000
December	6,690	2,410	3,900	240,000
January	5,090	3,140	3,950	243,000
February	4,040	2,820	3,420	197,000
March	3,660	2,820	3,210	197,000
April	5,320	3,140	4,240	252,000
May	24,100	5,800	13,700	842,000
June	34,000	19,400	26,600	1,580,000
July	25,500	4,000	13,000	799,000
August	12,200	2,660	7,970	490,000
September	11,300	6,260	9,170	546,000
The year	34,000	2,410	8,050	5,840,000
1912–13.				
October	7,760	6,310	6,970	429,000
November	6,860	4,870	5,840	348,000
December	5,090	3,140	3,940	242,000
January	3,790	1,920	3,110	191,000
February	3,980	2,770	3,330	185,000
March	6,230	3,610	4,190	258,000
April	17,900	6,500	10,100	601,000
May	32,400	12,400	19,500	1,200,000
June	32,400	15,300	25,000	1,490,000
July	22,000	3,890	12,500	769,000
August	12,800	2,620	5,250	323,000
September	9,000	6,100	7,710	459,000
The year	32,400	1,920	8,970	6,500,000
1913–14.				
October	6,640	5,610	6,010	370,000
November	6,360	5,370	5,710	340,000
December	5,370	2,690	4,150	255,000
January	4,800	2,930	4,060	250,000
February	4,480	2,130	3,360	187,000
March	4,280	3,700	3,960	243,000
April	16,500	3,700	9,650	574,000
May	24,400	13,200	18,000	1,110,000
June	35,500	11,600	21,100	1,260,000
July	10,800	3,170	6,360	391,000
August	5,610	2,470	3,700	228,000
September	5,980	2,850	4,360	259,000
The year	35,500	2,130	7,540	5,470,000

The next station below the Blackfoot station is at Neeley, Idaho. Portneuf River and Bannock Creek and large amounts of spring water enter Snake River between these stations. The station at Neeley, which was established March 17, 1906, is the oldest on the river, and the record which has been obtained there is of great value in the interpretation of the flow of the river and in the formulation of plans for its utilization. The hydrometric data procured at the Neeley station have been published in the water-supply papers of the United States Geological Survey.[15]

This record may be regarded as a continuation of that obtained at Montgomery's Ferry near Minidoka during the years 1895–1899 and 1901–1910. There is not much inflow and practically no diversions between those stations.

Snake River probably receives a relatively small amount of direct inflow from the Fort Hall Indian Reservation, but its tributaries, Blackfoot River, Portneuf River, and Bannock Creek, which drain most of the reservation, are important streams.

BLACKFOOT RIVER BASIN.

Blackfoot River forms the north boundary of the reservation from the northeast corner to its confluence with the Snake. The sources of Blackfoot River are chiefly in the Preuss Range, 40 miles east of the reservation, in a region of high relief, well forested, and yielding a high run-off. After leaving the mountains the river flows on the surface of an extensive lava plateau. This plateau extends in general from the Caribou, Preuss, and Aspen ranges on the east to the Portneuf Range on the west. It is not continuous, however, for many hills and mountains which antedate the lava sheet project through it and break up the surface of the plateau into a number of intermountain areas.

Throughout the eastern part of this lava plateau Blackfoot River flows with a gentle gradient through an open valley that is but slightly intrenched in the lava surface. In T. 5 S., R. 40 E., the river enters a canyon (Pl. XII) through which it flows for a distance of about 40 miles. The depth of the canyon is at first moderate, but it gradually increases northwestward and reaches a maximum in T. 3 S., R. 38 E. Here the black basalt walls are about 400 feet high, very steep, in fact, vertical, and in places but a few hundred feet apart. The gradient of the stream through portions of the canyon is about 100 feet to the mile, and the white and green turbulent waters of the

[15] U. S. Geol. Survey Water-Supply Papers 214, p. 76, 1907; 252, pp. 212–214, 1910; 272, pp. 255–257, 1911; 292, pp. 297–300, 1913; 312, pp. 271–273, 1915; 332, pp. 287–299, 1916; 362, pp. 269–271, 1917; 398, pp. 24–26, 1916; 413, pp. 27–28, 1918.

A. LOWER PORTION OF BLACKFOOT RIVER CANYON AND ADJACENT SNAKE RIVER VALLEY.

B. CANYON OF BLACKFOOT RIVER, SEC. 10, T. 3 S., R. 38 E., SHOWING RELATION OF CLIFFS AND TALUS SLOPES TO RIVER.

river rushing through the blackness of the canyon present an impressive picture.

After leaving the canyon in sec. 11, T. 2 S., R. 37 E., the river enters the valley of Snake River, which here flows across a broad plain that was developed in the Gibson cycle, as described by Mr. Mansfield. In an earlier cycle Blackfoot River built a large alluvial fan at the mouth of the canyon. Much of this deposit has since been removed by the stream, but the uneroded portion now forms a terrace on the north side of the river. Across the valley of Snake River the Blackfoot flows practically on the Gibson surface, and has a slight gradient. The drainage basin of Blackfoot River has an area of about 1,070 square miles.

Gaging stations for measuring the flow of Blackfoot River have been established at several points along its course. The first of these stations was established April 17, 1903, near Presto, a former post office that was located about 5 miles below the mouth of the canyon. This station was discontinued December 31, 1909. It has, however, been practically replaced by a station that was established June 26, 1909, at a more favorable location about 1½ miles above the mouth of the canyon. The measurements obtained at this station, known as "Blackfoot River near Shelley, Idaho," indicate the entire flow of the river, as there are no large tributaries below and no diversions of consequence above. The observations at the Presto station have been published in water-supply papers,[16] and only a summary of the discharge of the river as computed therefrom is given here.

Monthly discharge of Blackfoot River near Presto, Idaho, for 1904–1909.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1904.				
June	975	233	536	31,890
July	216	150	179	11,010
August	182	150	161	9,900
September	216	182	198	11,780
October	269	216	251	15,430
November	269	216	230	13,680
December 1-10	269	216	238	4,721
The period				98,410
1905.				
March 5-31	335	166	256	13,710
April	498	269	412	24,520
May	606	242	368	22,630
June	233	142	183	10,890
July	121	76	91.2	5,608
August	536	64	100	6,149
September	121	82	89.0	5,296
The period				88,000

[16] U. S. Geol. Survey Water-Supply Papers 135, p. 186, 1905; 178, p. 106, 1906; 214, p. 84, 1907; 252, p. 281, 1910; 272, p. 284, 1911.

Monthly discharge of Blackfoot River near Presto, Idaho, for 1904–1909—Contd.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1905–6.				
October	150	121	138	8,485
November	166	121	145	8,628
December	216	107	177	10,880
January			[a]150	9,220
February			[a]150	8,330
March	349		196	12,100
April	1,350	150	552	32,800
May	1,040	602	813	50,000
June	960	272	582	34,600
July	290	100	179	11,000
August	162	88	113	6,950
September	215	154	183	10,900
The year				204,000
1906–7.				
October	253	197	225	13,800
November	273		254	15,100
December			[a]250	15,400
January			[a]250	15,400
February	458		304	16,900
March	470	234	321	19,700
April	2,370	400	1,460	86,900
May	1,590	1,270	1,430	87,900
June	1,290	766	1,020	60,700
July	714	293	391	24,000
August	314	224	256	15,700
September	283	253	269	16,000
The year				367,000
1907–8.				
October	367	283	328	20,200
November	378	335	366	21,800
December	422		309	19,000
January			[a]250	15,400
February			[a]200	11,500
March	470		291	17,900
April	792	411	578	34,400
May	447	284	339	20,800
June	696	304	491	29,200
July	284	124	163	10,000
August	159	117	134	8,240
September	175	130	149	8,870
The year				217,000
1908–9.				
October	284	167	237	14,600
November	274	227	249	14,800
December	264		217	13,300
January	344	200	246	15,100
February	284	227	260	14,400
March	264	175	222	13,600
April	1,960	227	660	39,300
May	1,960	1,440	1,700	105,000
June	1,680	578	1,060	63,100
July	566	253	364	22,400
August	263	197	227	14,000
September	356	234	282	16,800
The year				346,000
1909.				
October	378	215	336	20,700
November			352	20,900
December			[a]500	30,700
The period				72,300

[a] Estimated.

The data for the station near Shelley have also been published.[17] The following table gives the discharge of the river for the period of record as computed therefrom:

Monthly discharge of Blackfoot River near Shelley, Idaho, for 1909–1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1909.				
June 26–30	757	586	649	6,440
July	586	308	385	23,700
August	284	241	262	16,100
September	304	248	289	17,200
October	343	304	336	20,700
November	....	....	331	19,700
The period	....	....	....	104,000
1910.				
April 2–30	1,100	988	1,050	60,400
May	1,060	195	588	36,200
June	236	168	214	12,700
July	165	39	89.1	5,480
August	500	107	349	21,500
September	659	148	508	30,200
The period	....	....	....	166,000
1910–11.				
October	109	69	85.4	5,250
November	85	63	72.9	4,340
December	111	50	73.1	4,490
January	553	50	103	6,330
February	277	35	104	5,780
March	325	35	113	6,950
April	432	138	216	12,900
May	215	135	179	11,000
June	636	130	261	15,500
July	422	123	266	16,400
August	308	130	210	12,900
September	195	96	131	7,800
The year	636	35	151	110,000
1911–12.				
October	121	69	90.8	5,580
November	83	55	65.8	3,920
December	58	45	53.1	3,260
January	97	56	76.5	4,700
February	149	70	85.8	4,940
March	114	80	90.6	5,570
April	180	93	134	7,970
May	649	160	442	27,200
June	372	177	296	17,600
July	490	309	374	23,000
August	516	418	466	28,700
September	490	110	420	25,000
The year	649	45	217	157,000
1912–13.				
October	531	320	487	29,900
November	307	85	136	8,090
December	93	65	79.5	4,890
January	74	62	67.2	4,130
February	238	61	122	6,780
March	708	203	345	21,200
April	1,280	796	1,040	61,900
May	1,200	829	990	60,900
June	1,000	582	828	49,300
July	764	661	722	44,400
August	764	684	720	44,300
September	727	637	659	39,200
The year	1,280	61	518	375,000

[17] U. S. Geol. Survey Water-Supply Papers 272, p. 282, 1911; 292, p. 333, 1913; 312, p. 300, 1915; 332, p. 321, 1916; 362, p. 307, 1917; 393, p. 57, 1916.

Monthly discharge of Blackfoot River near Shelley, Idaho, for 1909–1914—Con.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1913–14.				
October	637	133	208	12,800
November	147	126	138	8,210
December	....	....	[a] 158	9,720
January	....	....	[a] 191	11,700
February	....	....	[a] 142	7,890
March	319	96	235	14,400
April	764	299	544	32,400
May	796	514	589	36,200
June	897	745	807	48,000
July	745	696	722	44,400
August	702	109	559	34,400
September	672	137	544	32,400
The year	897	....	404	293,000

[a] Monthly mean estimated largely from records at station near Henry.

A gaging station has also been established on Blackfoot River near Henry, 1 mile below the dam of the Blackfoot River reservoir of the Indian Irrigation Service and approximately 37 miles above the Shelley station. The records of the measurements made at the Henry station indicate the amount of water released from storage. This station is not located on the reservation and those interested will find the records published elsewhere.[18]

A number of small streams enter Blackfoot River between the Henry and the Shelley gaging stations. Several of these streams rise on the eastern slope of that portion of the Portneuf Range which extends northward into the reservation. The size of these tributaries may be judged from the following measurements made by E. C. La Rue, October 10–15, 1909, during the period of low flow: Deadman Creek, 0.39 second-foot; Beaver Creek, 0.86 second-foot; Wood Creek, 3.14 second-feet; Tenmile Creek, 0.43 second-foot.

Below the Shelley gaging station Garden and Lincoln creeks, which traverse the Fort Hall Indian Reservation, are tributary to Blackfoot River. Garden Creek is very small. Lincoln Creek drains an area of perhaps 40 square miles. Its flow is reported by E. C. La Rue to range from 3 to 75 second-feet. He estimated the discharge at a section half a mile above old Fort Hall to have been 3.8 second-feet on July 14, 1911. At low stages the flow of the stream sinks in the sand before reaching Blackfoot River.

During the season of 1910 a number of discharge measurements were made of the flow of Blackfoot River near its mouth, which afford an indication of the degree of utilization of the water of Blackfoot River during the irrigation season:

[18] U. S. Geol. Survey Water-Supply Papers 252, p. 231, 1910; 272, p. 279, 1911; 292, p. 331, 1913; 312, p. 298, 1915; 332, p. 318, 1916; 362, p. 305, 1917; 393, p. 55, 1916.

Discharge measurements of Blackfoot River near its mouth during the year ending Sept. 30, 1910.

[W. R. King, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
July 30	1.70	20.4	Aug. 17	1.50	20.7
Aug. 3	1.51	21.15	20	1.93	69.0
8	1.50	21.2	25	2.42	128.4
12	1.50	19.8			

PORTNEUF RIVER BASIN.

Portneuf River and its tributaries drain the greater part of the eastern and southern portions of the reservation.[19] The river rises on the eastern slope of the northward extension within the reservation of the Portneuf Range, and a short distance below its source it enters a fairly broad intermontane valley, through which it flows southward for about 10 miles. In the vicinity of Chesterfield, near the boundary of the reservation, this valley opens into a broad lava plain, which resembles that in the upper portion of the Blackfoot River drainage. This lava plain, called Portneuf Valley, has an average width of about 6 miles, an elevation of 5,300 to 5,500 feet, and a length of about 25 miles southeastward to Bear River.

Portneuf River flows southward along the west margin of the valley for about 8 miles and then leaves through a gap near the southwest corner. In this valley Topons Creek is tributary to Portneuf River from the west, and Eighteenmile, Moses, and Twentyfourmile creeks from the east.

After leaving Portneuf Valley the river flows southward for about 10 miles and then westward for about the same distance through a picturesque canyon cut across the Portneuf Range. In this portion of its course the Portneuf has a steep gradient and falls about 600 feet between Pebble and McCammon. Pebble Creek, Fish Creek, and Dempsey Creek are the largest tributaries, each draining a portion of the Portneuf Range. Near Dempsey a number of hot springs add materially to the flow of the river.

At McCammon Portneuf River enters Marsh Valley, a broad structural valley which lies between the Portneuf and Bannock ranges. The river takes a northward course along the east side of Marsh Valley for a distance of about 10 miles. This valley is drained chiefly by Marsh Creek, which flows northward along the center of

[19] Portneuf River is stated by Capt. Nathaniel J. Wyeth to have been named "from a man killed near it": The correspondence and journals of Capt. Nathaniel J. Wyeth, 1831–1836: Sources of Oregon History, vol. 1, pts. 3–6 incl., p. 162, Oregon Univ., Contrib. Dept. Economics and History, Eugene, Oreg., 1899.

the valley and, after paralleling Portneuf River for a considerable distance, finally joins it.

The river leaves Marsh Valley through a deep, gorgelike valley cut across the Bannock Range, flows with a moderate slope westward for about 6 miles and then turns to the northwest into a more open valley, in which lies the city of Pocatello. Rapid Creek, Indian Creek, City Creek, and Pocatello Creek are the more important tributaries in this vicinity.

Westward from Pocatello the river is intrenched in the alluvial deposits of the Gibson cycle. Its valley gradually broadens to the west and merges into the recent flood plain of Snake River, locally called the "Fort Hall bottoms." The lower 12 miles of its course is across the reservation. Across the flood plain the stream is sluggish. Near its mouth it receives a large volume of water from Ross Fork and Spring Creek.

No station for measuring the flow of Portneuf River has been maintained on the reservation. On September 8, 1910, a station was established near Pebble, in sec. 26, T. 7 S., R 38 E., on the west side of Portneuf Valley. The data obtained at this station have been published in several water-supply papers[20] and a summary of the discharge of the river at this station follows:

Monthly discharge of Portneuf River near Pebble, Idaho, for 1910–1913.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1910.				
September 8–30	43	39	39.3	1,790
October	47	47	47.0	2,890
November	66	47	51.5	3,060
December	66	39	52.6	3,230
The period				11,000
1910–11.				
October	47	47	47.0	2.890
November	66	47	51.5	3,060
December	66	39	52.6	3,230
January	624	47	99.6	6,120
February	696	56	115	6,390
March	345	56	202	12,400
April	249	117	163	9,700
May	233	165	190	11,700
June	152	73	113	6,720
July	102	45	61.1	3,760
August	56	32	42.8	2,630
September	56	39	45.7	2,720
The year	624	32	98.6	71,300
1911–12.				
October	66	47	56.8	3,490
November	76	39	55.8	3,320
December	43	39	40.4	2,480
January	52	39	45.8	2,820
February	52	46	48.8	2,810
March	72	46	54.5	3,350

[20] U. S. Geol. Survey Water-Supply Papers 292, p. 340, 1913; 312, p. 308, 1915; 332, p. 344, 1916; 362, p. 335, 1917.

Monthly discharge of Portneuf River near Pebble, Idaho, for 1910–1913—Contd.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
April	312	62	176	10,500
May	365	126	247	15,200
June	317	103	220	13,100
July	98	39	66.8	4,110
August	77	50	62.2	3,820
September	57	46	50.5	3,000
The year	365	39	93.6	68,000
1912–13.				
October	120	48	72.6	4,660
November	103	45	67	3,990
December	51	36	40	2,460
January	49	34	42.6	2,620
February	51	49	50.3	2,790
March	462	49	89.9	5,530
April	537	140	206	12,300
May	216	94	173	10,600
June	144	82	113	6,720
July	132	54	74.6	4,590
August 1–15	78	41	57.1	1,700
The period				57,800

The station near Pebble was discontinued on August 15, 1913. At the beginning of that year, however, a station was established at a point in sec. 23, T. 9 S., R. 37 E., 16 miles downstream from the Pebble station. The new station, at Topaz, is in the lower part of Portneuf Canyon and a short distance above the headgate of the main canal of the Portneuf-Marsh Valley Irrigation Co. A summary of the discharge at this station follows:

Monthly discharge of Portneuf River at Topaz, Idaho, for 1913 and 1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1913.				
January 12–31	163	156	161	6,350
February	211	163	184	10,200
March	679	202	269	16,500
April	902	251	412	24,500
May	449	266	380	23,400
June	247	170	196	11,700
July	285	156	189	11,600
August	186	128	150	9,220
September	170	141	157	9,340
The period				123,000
1913–14.				
October	202	163	185	11,400
November	266	194	220	13,100
December	186	170	180	11,100
January	194	170	183	11,300
February	211	170	189	10,500
March	512	202	321	19,700
April	770	346	575	34,200
May	593	413	533	32,800
June	565	285	373	22,200
July	368	266	299	18,400
August	285	178	230	14,100
September	285	163	212	12,600
The year	770	163	292	211,000

A station was also maintained on Portneuf River near Pocatello for portions of the years 1897 to 1899. A new station was established within the city limits on August 31, 1911, below all important diversions. The flow at this station indicates the approximate flow of Portneuf River at the reservation boundary 6 miles below. The complete record at this station has been published by the Survey,[21] and only a summary of the discharge is given here.

Monthly discharge of Portneuf River at Pocatello, Idaho, for 1912–1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1912–13.				
October	376	271	323	19,900
November	400	290	347	20,600
December	353	220	259	15,900
January			[a] 215	13,200
February	331		[a] 243	13,500
March	535	242	391	24,000
April	915	535	688	40,900
May	695	300	485	29,800
June	331	86	160	9,520
July	353	53	129	7,930
August	86	53	65.1	4,000
September	187	70	146	8,690
The year	915	53	287	208,000
1913–14.				
October	270	187	225	13,800
November	353	260	310	18,400
December	290	196	242	14,900
January	425	196	286	17,600
February	599		380	21,100
March	664	454	521	32,000
April	1,080	509	818	48,700
May	958	425	794	48,800
June	661	270	411	24,500
July	353	153	220	13,500
August	251	130	165	10,100
September	310	161	240	14,300
The year	1,080	130	384	278,000

[a] Estimated.

At Wade's ranch, 11 miles northeast of American Falls and a short distance west of the reservation boundary, a station was established on Portneuf River on July 30, 1910, and maintained during that season. The gage is nailed to a pole of the right-hand bent of the highway bridge over the river on the road from American Falls to Horse Island. The measuring station is located 300 feet above the bridge. Measurements are made from a rowboat.

Measurements at this station indicate the flow of Portneuf River below the mouth of Spring Creek and Ross Fork and above the mouth of Bannock Creek. Ross Channel of Snake River, which branches from the main channel at the head of Horse Island, enters the Portneuf a short distance above the station, and the discharge through this channel must accordingly be deducted from the measurements at the gaging station to give the net flow of Portneuf River.

[21] U. S. Geol. Survey Water-Supply Papers 362, p. 99, 1917; 393, p. 81, 1916.

This station was established in cooperation with the United States Reclamation Service, in order to afford an indication of the amount of water contributed to Snake River from this source during the irrigation season. As the record of this station has not been published elsewhere, it is given here in full.

Discharge measurements of Portneuf River near Wade's ranch during the year ending Sept. 30, 1910.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Second-feet.*
July 30	H. L. Stoner	5.50	1,516.2
Aug. 9	Stoner and Crandall	5.50	1,443.8
21	....do	5.56	1,523.8
28	H. L. Stoner	5.50	1,573.6

Daily gage height, in feet, of Portneuf River near Wade's ranch for the year ending Sept. 30, 1910.

Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.
1		5.5	5.6	16		5.5	5.7
2		5.5	5.6	17		5.5	5.72
3		5.5	5.6	18		5.55	
4		5.5	5.6	19		5.58	
5		5.5	5.6	20		5.58	
6		5.5	5.6	21		5.55	
7		5.5	5.6	22		5.57	
8		5.5	5.6	23		5.57	
9		5.5	5.62	24		5.58	
10		5.5	5.62	25		5.59	
11		5.5	5.62	26		5.6	
12		5.5	5.62	27		5.6	
13		5.5	5.64	28		5.6	
14		5.5	5.68	29		5.6	
15		5.5	5.7	30		5.6	
				31	5.5	5.6	

The flow of Ross Channel was measured by Messrs. Stoner and Crandall on August 9, 1910, at the ford between the reservation and Horse Island and found to be 2.8 second-feet. The flow through this channel during July and August, 1910, was constant.

The discharge measurement of August 9 should be given preference over that of July 30 because of better soundings. It appears, then, that the discharge of Portneuf River ranged during the period of measurement from 1,440 to about 1,700 second-feet.

The important tributaries of Portneuf River within the reservation are Ross Fork, Spring Creek, and Michaud Creek. Ross Fork is formed by the junction of two principal forks which rise on the west slope of the Portneuf Range. It has a westward course, at first through a broad valley that is eroded in the older rocks of the eastern part of the reservation and farther to the west across the broad terrace of the Gibson cycle. Toward the west edge of the terrace the stream flows through a narrow valley, which it has cut in its

descent to the level of the Snake River bottoms. After leaving the terrace it flows into Portneuf River.

No gaging station has been established on Ross Fork. A measurement by E. C. La Rue, on July 18, 1911, indicated a flow of 10.3 second-feet on the North Fork of Ross Fork. The minimum flow is somewhat less and may in some years be as low as 6 second-feet.

Clear Creek flows into Ross Fork a short distance above its mouth and contributes by far the larger part of its volume. This stream rises near the east margin of the Fort Hall bottoms and follows quite closely the base of the Gibson terrace. The stream is fed by springs which rise in places throughout the bottoms. No measurements of its flow are recorded, but it appears to discharge several hundred second-feet.

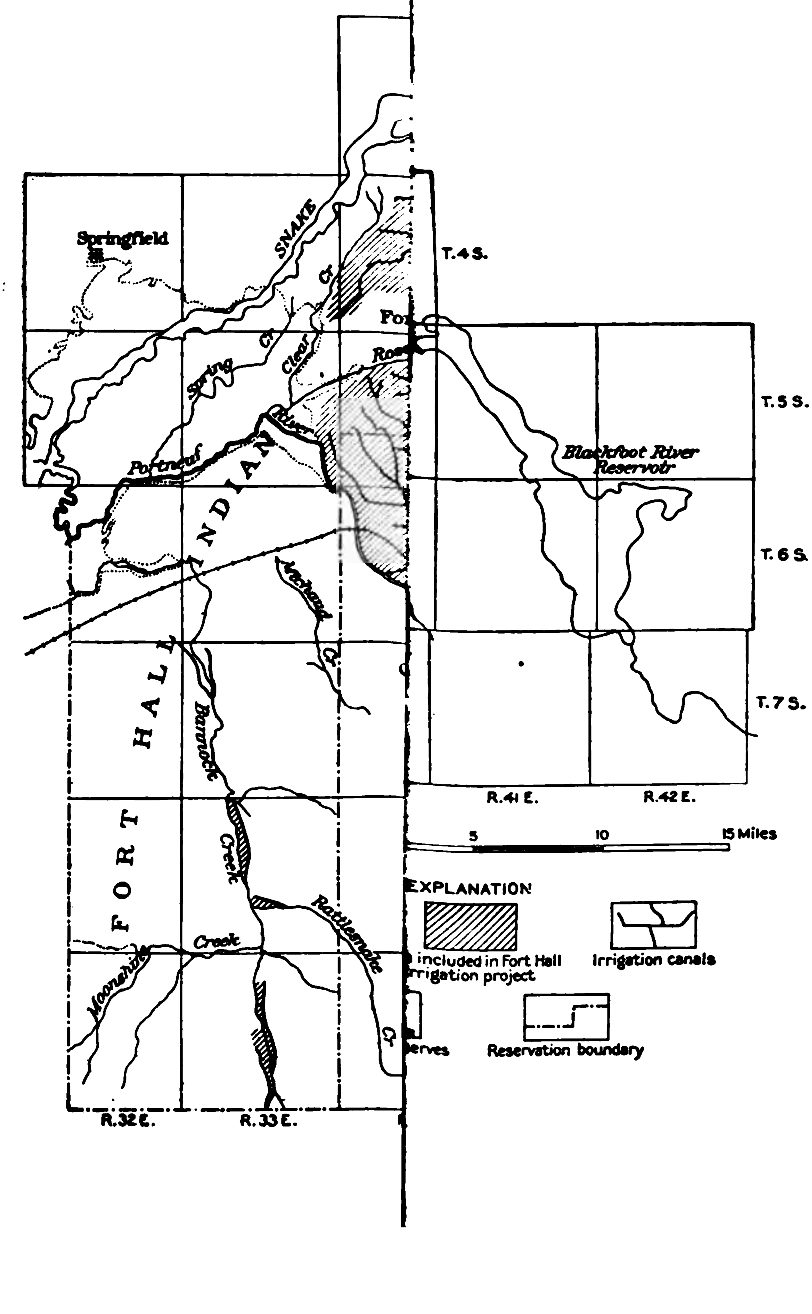
Spring Creek also heads in large springs, which rise near the north end of the Fort Hall bottoms. It flows parallel to Snake River through practically the entire extent of the bottoms and unites with the Portneuf a few miles above its mouth. The stream is remarkable for the large flow which it receives from underground sources, measurements of discharge indicating an average minimum of about 1,500 second-feet. The slope of the stream is but 2 or 3 feet to the mile. The water is beautifully clear, and in most lights has a pronounced blue color.

BANNOCK CREEK BASIN.

Bannock Creek has its source in Arbon Valley about 15 miles south of the reservation boundary. For over 30 miles it follows a generally northward course through a broad valley which lies between the Bannock Range on the east and the Rock Creek Mountains on the west and enters the Portneuf a short distance above the mouth. Its larger tributaries are Knox, Moonshine, and Starlight creeks from the west and Rattlesnake Creek from the east. The following miscellaneous discharge measurements have been made at different points in the drainage basin by engineers of the Indian Irrigation Service and of the Geological Survey:

Miscellaneous measurements in Bannock Creek basin.

Date.	Stream.	Locality.	Discharge.
1909.			*Sec.-ft.*
Sept. 26	West Branch of Bannock Creek	SE. ¼ sec. 34, T. 9 S., R. 33 E.	3.7
26	East Branch of Bannock Creek	do	24.7
27	Bannock Creek	T. 9 S., R. 33 E., sec. 27, south line	37.8
27	do	Sec. 34, T. 8 S., R. 33 E., below mouth of Moonshine Creek.	35.5
27	Rattlesnake Creek	NE. ¼ sec. 28, T. 8 S., R. 33 E.	9.3
27	Bannock Creek	Above mouth of Rattlesnake Creek	40
27	do	Below mouth of Rattlesnake Creek	51.2
1910.			
Aug. 9	do	1 mile below Horse Island	32.68
21	do	do	33.11
28	Tributary of Bannock Creek	Short distance from mouth	2.03


Springfield
SNAKE
Spring Cr.
Clear Cr.
Portneuf River
FORT HALL INDIAN
Bannock Creek
Rattlesnake Cr.
Moonshine Creek
Blackfoot River Reservoir
T.4 S.
T.5 S.
T.6 S.
T.7 S.
R.32 E.
R.33 E.
R.41 E.
R.42 E.
5 10 15 Miles
EXPLANATION
included in Fort Hall irrigation project
Irrigation canals
erves
Reservation boundary

The discharge measurements made in August, 1910, were obtained at a point about 600 feet above the highway bridge on the road from American Falls to Horse Island, a short distance west of the reservation boundary. The total discharge of Bannock Creek into Portneuf River is obtained by adding to the discharge at this station that of the small tributary given in the above table. The total flow of Bannock Creek at the mouth thus appears to have been about 35 second-feet during July and August, 1910.

GROUND WATER.

Consideration of the ground-water supply of the Fort Hall Indian Reservation is divided naturally into a discussion of conditions in the eastern and southern mountain and valley regions and in the alluvial plains of the Snake River valley. (See Pl. XIII.)

OCCURRENCE IN THE MOUNTAINOUS AREAS.

But a short time was devoted to studying in the field the occurrence of ground water in the more mountainous areas. Numerous springs and small streams make these portions of the reservation generally well watered. The faulting and flexuring of the rocks, described by Mr. Mansfield, which have resulted in the discontinuity of water-bearing beds, have apparently caused complex ground-water conditions. Circulation of ground water is doubtless largely influenced by lines of fracture, and the return of ground water to the surface along fault lines appears to explain the location of some of the mountain springs.

In the narrow valleys which head between the mountain spurs small amounts of ground water may be stored in narrow belts of alluvium along the streams. In the larger valleys, like those of the upper Portneuf River, of Ross Fork, and of Bannock Creek, no difficulty will generally arise in obtaining water for domestic use from shallow wells in the valley fill. Two wells, both shallow, are reported in Bannock Valley, one on the allotment of Francis Mosho and one at the reservation farm in the S. ½ NE. ¼ sec. 32, T. 7 S., R. 33 E., occupied by Jesse White. A well drilled to a depth of 76 feet on the reservation farm in Ross Fork valley, in the SW. ¼ SW. ¼ sec. 31, T. 4 S., R. 36 E., passed through 20 feet of alluvium and then entered rock. The water level was not ascertained but is reported to be less than 10 feet from the bottom. The well is said to have cost $210.

OCCURRENCE IN SNAKE RIVER VALLEY.

Ground-water conditions in the valley of Snake River are of greater economic importance than in the areas just discussed for the reason that surface-water supplies are less abundant.

The terrace of the Gibson cycle averages 6 to 8 miles in width across the Fort Hall Indian Reservation and north of Blackfoot River extends as a broad plain to Idaho Falls and beyond. Southwestward it narrows abruptly and disappears as a conspicuous topographic feature in the vicinity of American Falls. Throughout the reservation the west boundary of the terrace, a steep bluff that forms an abrupt descent to the Snake River bottoms, is usually sharply defined. In the northwestern part of T. 4 S., R. 34 E., just south of Big Butte, the height of the bluff is only about 15 feet, but it gradually increases southward and near Cedar Butte in the northeastern part of T. 4 S., R. 33 E., is about 60 feet. The terrace is dissected by the valleys of Ross Fork and Portneuf River, more deeply by the latter. South of the Portneuf, however, it continues with only minor irregularities to the west boundary of the reservation.

So far as observed, only sands and gravels are exposed in the margin of the terrace facing Snake River, although some of the wells drilled in the eastern part of the terrace are reported to have penetrated lava strata. The sands and gravels that compose the terrace appear to have a slight dip in the direction of Snake River, owing presumably to conditions of sedimentation rather than to subsequent tilting. They represent débris brought from areas of high relief and deposited at a time when the base-level of the region was perhaps 100 feet higher than at present.

On the west side of Snake River, opposite the reservation, is a terrace which corresponds in elevation to that of the Gibson cycle on the reservation. Its eastern margin is largely made up of exposures of Snake River lava. No corresponding lava outcrops appear on the reservation side. As there is no evidence of faulting or other disturbance the conclusion is probably justified that the uppermost sheet of the Snake River lava has never extended much farther east than the west bank of the river. The Gibson terrace thus appears to be the remnant of a deposit of alluvial material which originally extended westward across the present Snake River bottoms and met the eastern margin of the lava.

Either through change in base-level or through headward erosion the Snake River later began downcutting. Its course was such that the entrenching was done in the alluvium and not in the lava, and in consequence the river was able to accomplish rapid work in clearing out a valley at a level below the Gibson terrace. The river has now removed about one-third of the alluvium deposited against the eastern margin of the lava during the Gibson cycle. On its right bank most of the alluvium has been eroded. Remnants may, however, be observed at intervals along the road from American Falls to Blackfoot.

The alluvium of the Gibson terrace has a texture favorable for carrying water. The gravels are coarse and have large interstices, and it is probable that this influences the depth to the water table under most of the terrace, the gravels providing a ready exit for the ground water in the direction of Snake River. The location of the water table with relation to the surface of this terrace is indicated by the following data relating to wells:

Wells on the Gibson terrace.

No.	Owner.	Location.	Depth of well.	Depth to water level.
			Feet.	*Feet.*
1	George W. Tenday	E. ½ SE. ¼ SE. ¼ sec. 36, T. 3 S., R. 34 E	48	44
2	Ralph Dixie	Lot 5, SE ¼ NE. ¼ sec. 9, T. 3 S., R. 35 E	67	[a] 47
3	Charley Diggie	E. ½ NW. ¼ SW. ¼ sec. 10, T. 3 S., R. 35 E	47	40±
4	Peter Jim	S. ½ SW. ¼ SE. ¼ sec. 10, T. 3 S., R. 35 E		
5	Jones Johnson	W. ½ NW. ¼ NE. ¼ sec. 17, T. 3 S., R. 35 E	38	34
6	do	do	50	41
7	Jimmie Smart	E. ½ NE. ¼ NW. ¼ sec. 19, T. 3 S., R. 35 E	31	22
8	Tea Pokibro	W. ½ NE. ¼ NW. ¼ sec. 22, T. 3 S., R. 35 E	50+	
9	Captain Willie	E. ½ NW. ¼ NE. ¼ sec. 29, T. 3 S., R. 35 E	51	41
10	Presbyterian Mission	SW. ¼ SE. ¼ sec. 29, T. 3 S., R. 35 E	84	40
11	Billy George	E. ½ NW. ¼ NW. ¼ sec. 32, T. 3 S., R. 35 E	80±	40±
12	William Penn	E. ½ SE. ¼ NE. ¼ sec. 1, T. 4 S., R. 34 E	50±	44
13	Frank Trouchart	E. ½ NE. ¼ NW. ¼ sec. 3, T. 4 S., R. 34 E		
14	Dick Burns	N. ½ SE. ¼ sec. 26, T. 4 S., R. 34 E	30	20
15	Tom Madzeweyu	SW. ¼ NE. ¼ sec. 35, T. 4 S., R. 34 E		13
16	Agency	NW. ¼ SW. ¼ sec. 36, T. 4 S., R. 34 E	108	50±
17	Mary M. Hutchinson	E. ½ SE. ¼ NW. ¼ sec. 36, T. 4 S., R. 34 E	76	55±
18	Oregon Short Line R. R.	NW. ¼ SW. ¼ sec. 36, T. 4 S., R. 34 E	147	
19	Agency	do	115±	
20	do	do	125±	
21	Episcopal Mission School	SW. ¼ SE. ¼ sec. 36, T. 4 S., R. 34 E	100+	
22	Agency Farm	SW. ¼ NW. ¼ sec. 36, T. 4 S., R. 35 E	83	54
23	Hiram Faulkner	W. ½ SE. ¼ NE. ¼ sec. 29, T. 4 S., R. 35 E	[b] 102	82
24	M. Y. LeSieur	W. ½ NE. ¼ NE. ¼ sec. 2, T. 5 S., R. 34 E	56	36±
25	Shorty George	N. ½ NE. ¼ NE. ¼ sec. 11, T. 5 S., R. 34 E	41	35
26	Jessie P. Blakesley	N. ½ NE. ¼ SE. ¼ sec. 11, T. 5 S., R. 34 E	86	66±
27	Mamie Nahsie	SW. ¼ SE. ¼ SW. ¼ sec. 14, T. 5 S., R. 34 E		58
28	Rose Brady	W. ½ SE. ¼ SE. ¼ sec. 16, T. 5 S., R. 34 E	38	30±
29	Johnny Book	E. ½ SW. ¼ SW. ¼ sec. 17, T. 5 S., R. 34 E		28
30	Earl E. Cutler	W. ½ NW. ¼ SE. ¼ sec. 22, T. 5 S., R. 34 E	[c] 50	42
31	Ida Browning	W. ½ NE. ¼ SW. ¼ sec. 23, T. 5 S., R. 34 E	70	64
32	Ed Lavata	NE. ¼ sec. 1, T. 5 S., R. 35 E	100±	38
33	Reservation School	NW. ¼ SW. ¼ sec. 1, T. 5 S., R. 35 E	175	80
34	Charles Faulkner	NW. ¼ SE. ¼ sec. 1, T. 5 S., R. 35 E	220	23

[a] Yields 100 gallons a minute to pump without much lowering of water level.
[b] First water struck at 20 feet.
[c] Pumped by gasoline.

The evidence bearing on the quantity of water which can be obtained from the underflow in this area is meager. The well which supplies the railroad water tank at Ross Fork is pumped at the rate of 24 gallons a minute, and it is said that continuous pumping lowers the water surface in the well appreciably. The agency is supplied from a well pumped by an automatically controlled electric motor. The supply has proved ample for all purposes, including fire protection. The well owned by Ralph Dixie is reported to have yielded under test 100 gallons a minute without greatly lowering the water surface.

There is considerable seasonal fluctuation in the water level. The water table is lowest early in the spring and highest early in the fall, a difference in level of 3 or 4 feet being reported in some wells. The cause of this fluctuation is apparently the application of water to the irrigated lands, the water standing highest soon after the period of maximum irrigation.

Data are not available to indicate whether irrigation has affected the water level in this area. The establishment of bench marks at wells within the limits of the irrigation project and the taking of occasional readings of the depth to water is desirable, in order that if the rise of the water table under the irrigated area should prove to be progressive measures might be taken to prevent the eventual water-logging of the irrigated lands. The coarseness of the terrace alluvium is a factor of safety in this regard, because it will result in rapid movement of the ground water toward the river. With reasonable care in the use of water for irrigation it should be possible to avoid any serious difficulty from water logging.

The Fort Hall bottoms, the broad level plain which borders Snake River and which belongs to the Spring Creek cycle of erosion, begins as a narrow flat just west of Big Butte. It widens greatly in a short distance southward and attains a maximum width of about 5 miles near the junction of Ross Fork with Portneuf River. The plain slopes to the southwest at about the same gradient as that of Snake River itself, which is somewhat more than 2 feet per mile. The relief on the plain is slight; the streams which cross it, Spring and Clear creeks, flow practically on its surface; and the gravel banks along Snake River have a maximum height of only about 15 feet above the low-water stage of the river. Near Snake River the plain is cut up by high-water channels.

Cut banks along the river and placer miners' test pits indicate that the flat is immediately underlain by a deposit of coarse stream gravel, which in many places still has the form of old river bars. This deposit of gravel has, over a large area of the plain, been covered by a rich soil, which generally ranges in depth from 2 to 6 feet. Much of the area is covered by a luxuriant growth of wild grasses. The hay forms an important resource of the reservation, providing winter feed for the herds of the Indians. Portions of the plain, especially along the river, are covered with a growth of cottonwood and other deciduous trees. Other portions are swampy and under present conditions valueless except as they provide a feeding ground for large numbers of water fowl.

The water table is generally very near the surface. Places where it is more than 10 feet below the surface are exceptional, and its ıge depth is probably less than 5 feet. The surface soil of much

of the plain thus obtains through capillarity sufficient moisture to produce the hay crop. Between Spring Creek and the river there is, however, a tract where the water table is apparently too far below the surface to support a heavy growth of grass. This tract might be irrigated to advantage.

The most remarkable ground-water feature in this region is the presence of numerous large springs throughout the Fort Hall bottoms. (See pp. 19, 132, 136.) These springs contribute the large volume of 1,400 second-feet to the flow of Portneuf River. This flow is remarkably constant, varying but little throughout the year and apparently not fluctuating from one season to another. Both Clear Creek and Spring Creek obtain practically all their flow from underground sources, as the area of their drainage basins is insignificant.

Clear Creek follows the edge of the bluff at the western border of the Gibson terrace. The springs which form it are individually small, but the flow probably aggregates 100 second-feet by the time it unites with Ross Fork. These springs do not seem to come out from beneath the terrace but rise from the midst of the plain without apparent relation to topographic features. Spring Creek has its source in a very large spring or group of springs near the south base of Big Butte, a prominent hill near the northwest corner of the reservation, and directly at the foot of the bluff that forms the margin of the narrow remnant of the Gibson terrace which fringes the south slope of the butte. Here a large volume of beautifully clear water wells up in a pool about 50 feet in diameter and flows southward through a marsh. At the bridge on the road from Fort Hall to Tilden Bridge Spring Creek is a deep, swift stream with a volume of perhaps 500 second-feet. Clear Creek practically parallels Snake River throughout the length of the bottoms.

These springs have great economic importance, for they contribute a large volume of water to Snake River at all seasons and furnish a constant supply for the irrigation of the lands around Twin Falls, even when the Snake goes dry at Blackfoot, as it has been known to do in very dry years. Considerable interest has thus been aroused in their origin, and several alternative hypotheses have been suggested to account for them. Their origin is thus attributed to (1) the reappearance of water lost into the underflow by seepage from Blackfoot River; (2) by seepage from Portneuf River; (3) by seepage from Snake River; (4) ground water which has accumulated in the gravels that underlie the Gibson terrace; (5) ground water which has been collected under the Snake River plain to the northwest and which has traveled southeastward along strata interbedded with or underlying the Snake River lava.

In considering the possibility that the water of these springs comes from Blackfoot River, reference must be made to the records of discharge of Blackfoot River which have been cited. It is at once apparent from an examination of the records obtained at the gaging station near Shelley, above all large diversions, that only in occasional months of high yield is the discharge of Blackfoot River as large as the flow of these springs, whereas the mean discharge of the river is in most years only about 10 per cent of the discharge of the springs. Practically the entire flow of Blackfoot River during the summer is diverted and used for irrigation, and the flow in the channel of the river below the head gate of the reservation canal is usually very small.

Investigations have been made by the United States Geological Survey at the request of the Indian Irrigation Service to determine the amount of water lost by seepage from Blackfoot River between the reservoir and the canal head gate. The results of the investigation made in 1909, which covered 42 miles of the river between Rockyford and Presto, indicated a gain of 1.10 second-feet in that distance, making allowance for all tributaries and diversions.[22] The other investigations, in November, 1912, and June, 1913, covered the portion of the river between the gaging station near Shelley, a short distance below Presto, and the head gate of the reservation canal. These investigations showed that no appreciable loss or gain in the flow occurs between these points except as the flow is increased or diminished, respectively, by surface tributaries or diversions. It may therefore be concluded that but little water passes into the underflow from the channel of Blackfoot River and that the volume of the flow of the river is entirely inadequate to feed these springs were it all to pass underground.

Portneuf River, because of large diversions for irrigation and the small volume of flow as compared with the springs, also appears inadequate as a source of supply. Furthermore, the springs are so situated topographically with relation to the river that it is difficult to understand how they can be in any way related.

Another explanation of the flow of the springs is that they represent the reappearance of the water of Snake River which has passed underground at points farther up the stream, perhaps in the irrigated district north of Blackfoot. There are, however, certain facts which are difficult to reconcile with this hypothesis. The springs show no tendency to fluctuate in volume, as would be expected if they were directly related to the flow of the river. Records of stream discharge sh[illegible] even in the periods of maximum flood on Snake River [illegible]orresponding increase in the flow of the springs. Even

[22] [illegible]S. Geol. Survey Water-Supply Paper 272, pp. 286–288, 1911.

in seasons when Snake River goes dry at Blackfoot the flow of the springs is practically undiminished.

The springs on the reservation are, however, not the only springs which add to the flow of Snake River between the mouth of Blackfoot River and American Falls. In the vicinity of Tilden and Springfield, on the west side of Snake River, there are a number of large springs which flow out of the Snake River lava, and some of them rise at a considerable elevation above the river. One of these, Donaldson's Spring, rises well toward the top of the lava terrace on the west side of the river at an elevation of about 60 feet above the river. The total volume of the springs on the west side of the river is, however, only a fraction of the total flow of the springs on the reservation.

If this water is derived from Snake River it must have entered the underflow a long distance upstream, for the slope of the river for a number of miles above the springs is small. Allowance must also be made for the difference in head produced by the friction of the water in passing through the rocks. When both these factors are considered it is difficult to see how the water of Donaldson's and other springs west of the river is derived from it.

The topographic relations of the springs on the east side of the river do not conclusively eliminate Snake River as the source of the water. Although perhaps none of the springs are less than 5 feet and some are fully 20 feet above the river, their similarity to springs west of the river makes it improbable that they have an essentially different origin. The fact that it is difficult to show that the springs on the west side have any definite connection with Snake River lends additional weight to the belief that the springs on the east side do not come from that source.

It is apparent that the 100 square miles of drainage area of the Gibson terrace is entirely inadequate to collect the large amount of water which the springs discharge. It is possible that the underflow from the terrace may contribute slightly to the discharge of these springs, but the aggregate from these sources constitutes in all probability but a small addition to their flow.

The hypothesis that the water comes from underneath the Snake River plain to the northwest and has a common origin with the water which flows from the springs on the west side of the river has much in its favor. The lava plains to the west of Snake River which have no surface drainage cover a very large area, 40 to 50 miles in width, that extends from far up the Snake River valley southward and westward across the State. The region that may be regarded as a possible catchment basin for these springs has an area of perhaps 3,000 square miles. It receives an average annual precipitation of 10 inches or more. Because of the extremely rough

broken character of the surface the proportion of the precipitation which enters the lava is doubtless high. To produce a continuous discharge of 1,400 second-feet approximately 1,000,000 acre-feet would have to enter the underflow annually, an amount equivalent to a depth of 6.3 inches on this area. It is well known that Big Lost and Little Lost rivers, which sink on the northwest side of the lava plains, contribute large amounts of water to the lavas. When all these factors are considered it appears that the underflow from this lava area is competent to account for the greater part if not all of the flow of these springs. The flow derived from such a source would be practically constant in volume and subject only to slight annual or seasonal changes.

A difficulty arises, however, in explaining how the water may have been carried eastward under the present channel of the river. As has been previously stated, the western bank of Snake River, throughout practically all that portion opposite the Fort Hall Indian Reservation, is formed by the exposed edge of the uppermost sheet or sheets of the Snake River lava. The river itself flows on a gravel bottom throughout this stretch, and as far as known no lava is exposed in its bed or in the entire plain adjacent to the river. At American Falls, 12 miles southwest, the river drops over the edge of a lower lava sheet, which is exposed on both sides of the river for some distance downstream from the falls. Northward this lava does not appear at the surface. If, however, this lava sheet, which might reasonably be expected to extend a considerable distance northward from American Falls, should project farther to the east than the overlying exposed sheets it may pass concealed under the bed of Snake River and underlie in part the Fort Hall bottoms. Water might then be carried either through the fissures of this lava sheet or through underlying alluvial deposits entirely under the bed of Snake River to the contact of the eastern margin of the lava with the terrace gravels and then follow this contact to the surface. Whatever may be the exact course of this water underground, it appears more reasonable to ascribe these springs to a deep underground source than to explain their origin in the other ways that have been suggested.

UTILIZATION OF WATER.

DOMESTIC USE.

The mountainous portions of the reservation contain abundant supplies of water, which are available for domestic use and for watering stock. It is improbable that the future needs of the reservation will [illegible] any extensive development of water for these uses in the more

rugged areas. Similarly water can readily be obtained in the Snake River bottoms either from streams or springs or from shallow wells.

On the Gibson terrace permanent and pure water supplies for ranches can generally be obtained by wells that range in depth from 50 to 100 feet. Wells are easily dug, but on account of the looseness of the gravels lining will ordinarily be required to prevent caving. Because of the porosity of the soil, drilled wells carefully cased are preferable to open wells as less likely to become contaminated from surface drainage.

The supply for the agency buildings at Fort Hall is obtained from a well pumped by an electric motor. The railroad water tank at Ross Fork is supplied by a steam pump which has a capacity of 28 gallons a minute.

IRRIGATION.

The principal irrigated areas on the reservation are in the valley of Bannock Creek and on the Gibson terrace, the Fort Hall irrigation project covering nearly all of that part of the terrace between Blackfoot River and Pocatello. The irrigated areas are indicated on the accompanying map.

Bannock Valley.—The ditches which divert from Bannock Creek are all small and each covers not more than three or four Indian ranches. The highest of these ditches diverts from the West Fork south of the reservation boundary and follows the west bank for about 3 miles. A second ditch diverts from the east bank in the NE. ¼ SW. ¼ sec. 22, T. 9 S., R. 33 E., and extends northward about 2 miles. Other ditches divert from Moonshine and Rattlesnake creeks. The largest ditch in the valley has its head gate in the SW. ¼ SE. ¼ sec. 21, T. 8 S., R. 33 E., and covers lands on the east side of the creek for a distance of about 4 miles.

The waters of Bannock Creek were adjudicated by a decree of the United States district court dated April 9, 1907. The Indians of Fort Hall Reservation were awarded a prior right to 16¼ second-feet of water from Bannock Creek, dating from April 1, 1887. Settlers on public lands on the head of Bannock Creek south of the reservation boundary were awarded junior rights, aggregating 19.6 second-feet.

The water right awarded to the Indians has not been extensively utilized, whereas the amount awarded the settlers has been largely put to beneficial use.

Fort Hall irrigation project.—The Fort Hall irrigation project contemplates the ultimate irrigation of 50,000 acres that lie principally on the Gibson terrace in the western part of the reservation. Of this area 38,000 acres are situated within the reservation and

12,000 acres lie south of the reservation boundary in the ceded area near Pocatello.

The project depends for its water supply on Blackfoot and Snake rivers. The waters of Blackfoot River have been appropriated under the laws of the State of Idaho. Applications were filed with the State engineer on September 3, 1907, for permits to appropriate the flow of Blackfoot River for storage in the Blackfoot River reservoir. These permits contemplated the impounding in the reservoir of 200,000 acre-feet annually, an amount approximately equivalent to a continuous flow of 280 second-feet.

By a decree of the district court the Fort Hall irrigation project was also allotted 600 second-feet from Snake River, with a priority dating from December 14, 1891. The water used under this decree is diverted from Snake River in sec. 31, T. 1 N., R. 37 E., near the village of Shelley and carried southward through the Idaho Canal to Blackfoot River. The point of discharge is in sec. 24, T. 2 S., R. 36 E., a few miles above the head gates of the project canals. The Idaho Canal is about 12 miles in length and was constructed with a capacity of 600 second-feet. Its principal use is as a feeder for this project, although large amounts of water wasted from irrigated lands in the vicinity of Blackfoot are carried through it.

The construction of the dam for the Blackfoot River reservoir was commenced in the summer of 1908. The dam (Pl. I, *B*) is situated in the NE. ¼ sec. 12, T. 5 S., R. 40 E., about 50 miles southeast of the city of Blackfoot. It is 40 feet in height above the bed of the river, 120 feet long at the bottom, and 250 feet long on the crest. It is a combined rock-fill and hydraulic-fill structure, with a concrete core wall, and the reservoir side is paved to prevent erosion. The outlet is through a tunnel at the south end of the dam, 200 feet long, which is lined with concrete and has a cross section of 90 square feet. The spillway is excavated in rock at the north end of the dam and has a width of 50 feet. The reservoir is about 17 miles in length and over 5 miles in maximum width, with an area of 15,000 acres and a capacity of 200,000 acre-feet. On June 30, 1916, it contained approximately 132,000 acre-feet of stored water.

The water released from storage is carried in the channel of Blackfoot River a distance of about 50 miles to the head gates of the two main canals of the project. The upper canal, which heads about 2 miles east of Blackfoot, was designed to carry 400 second-feet and to irrigate 30,000 acres. The heading is a rock-fill dam, in which are placed six concrete head gates. The canal follows the foothills on the east side of the project, extending in a southerly direction nearly
'o. Ross Fork is crossed by a concrete siphon 133 feet long.
, situated principally on ceded lands south of the reserva-

tion, is reached by a concrete siphon 4,500 feet long, which has a capacity of 200 second-feet. The lower canal covers about 20,000 acres between Blackfoot River and Ross Fork. It heads about a mile below the upper canal and has a capacity of about 250 second-feet. Its length is 10.5 miles.

As by far the greater part of the irrigable lands of the project is held by Indians, many of whom were not accustomed to irrigation farming, the agricultural development of the area has not been especially rapid. In the season of 1915, 18,542 acres were irrigated, of which 9,005 acres were in the ceded area; 7,447 acres were irrigated by the 209 Indian farmers on the project. Approximately 91,000 acre-feet of water was diverted from Blackfoot River in 1915, giving a duty of nearly 5 acre-feet at the point of diversion.

As the project is further developed and new lands are brought under cultivation the total amount of water required will necessarily increase, although after the soil is saturated the duty should be higher. It is probable that the project will ultimately require the diversion from Blackfoot River of 200,000 acre-feet annually. The length of the irrigation season is about 180 days from April 20 to October 10. In 1915 the percentage diversions by months were approximately as follows: April, 6; May, 14; June, 18; July, 29; August, 17; September, 11; and October, 5.

Portneuf project.—The portion of the Gibson terrace that lies on the south side of Portneuf River and extends toward American Falls is an area of excellent agricultural land which would become highly productive with irrigation. Approximately 40,000 acres of this land could be irrigated by a canal that would divert water from Portneuf River in T. 7 S., R. 35 E., about 10 miles southeast of Pocatello. The location of the canal follows the south bank of the river for a distance of about 16 miles before any irrigable lands are reached. An alternative plan of irrigation involves pumping from the Portneuf about 4 miles northeast of Pocatello. Under either plan the flow of Portneuf River during the irrigation season would have to be largely increased by providing additional storage in the upper drainage basin of that stream or by the diversion into the Portneuf of additional water from an adjacent drainage basin.

Fort Hall bottoms.—In the event that the American Falls reservoir is not constructed the irrigation of a portion of the Fort Hall bottoms by the diversion of the waters of Spring Creek appears possible. Surveys which would demonstrate the feasibility of such a plan have not been undertaken. The sheltered situation of the lands of the Fort Hall bottoms below the general level of the plains on either side gives them a somewhat more favorable climate which might be well adapted to growing the hardier fruits.

WATER POWER.

The water powers of the Fort Hall Indian Reservation are undeveloped, and their utilization, when it is accomplished, must be coordinated with the higher use of water for irrigation. The location of power plants and the amount of power which can be obtained are thus to a high degree dependent on the course of future irrigation development, some of the possibilities of which have been discussed.

Snake River.—The fall of Snake River along the western boundary of the reservation is but little more than 2 feet to the mile. No concentrations of fall which would afford opportunity for power development and no feasible dam sites occur along this portion of its course. At American Falls, 7 miles west of the reservation, a feasible dam site exists in secs. 19 and 20, T. 7 S., R. 31 E. A dam at this site with a height of 90 feet would create a reservoir with an estimated capacity of 3,036,000 acre-feet of water. The area overflowed would be approximately 70,000 acres, of which about 30,000 acres are within the reservation, the remainder being mainly private holdings.

This reservoir site is one of the principal features of the Bruneau extension irrigation project, by which it is proposed to irrigate a large tract of arid land that lies on the south side of Snake River between Salmon Falls Creek and Bruneau River. The water impounded in the American Falls reservoir would be released as required and permitted to flow down the channel of Snake River to Milner dam, the present diversion point of the Twin Falls irrigation systems. From the Milner dam the water would be conducted about 60 miles through the main canal to Salmon Falls Creek, beyond which the irrigable lands of the project are situated.

The flow of Snake River is in normal years greatest during May, June, and July, and in many years half of the annual discharge has occurred during those months. The normal flow up to the middle of July is thus largely in excess of the established demands for irrigation. After that time the flow decreases rapidly and becomes insufficient to supply all the lands dependent on the river. In consequence it is necessary to supply this deficiency by the storage of water during the early part of the irrigation season for release during the period of shortage. The United States Reclamation Service has constructed two reservoirs for this purpose, one at Jackson Lake, in northwestern Wyoming, the other, Lake Walcott, about 30 miles southwest of American Falls, Idaho. These reservoirs by no means impound all the surplus waters of Snake River, and it has been estimated that on the average about 1,400,000 acre-feet passes down Snake River during the irrigation season unutilized. In addition the normal flow during the nonirrigation season in an average [illegible] about 2,500,000 acre-feet, which makes a total of nearly

4,000,000 acre-feet now undiverted. In storing and making available most of this surplus flow the American Falls reservoir would serve an important function in the conservation of the flow of Snake River.

The construction of the reservoir and the attendant irrigation project is, however, a very large financial undertaking. The construction of the dam alone will require an outlay of several million dollars. It is probable that considerable time will elapse before the financing of the project can be accomplished. The magnitude of the project may even be so great as to make it unattractive to private capital and construction may have to await action by the Government.

Aside from its value for irrigation the American Falls reservoir would have an important effect on the development of water power on Snake River between American Falls and the Milner dam. Three power plants are now in operation in that portion of the river, two at American Falls and one at the Minidoka dam of the Reclamation Service, and there is a good water-power site about 6 miles below American Falls. The storage of water in the American Falls reservoir for irrigation use would tend to concentrate the flow of Snake River in the irrigation season and would consequently reduce the flow and the power output during the winter. Very large amounts of power would, however, be made available for irrigation pumping and the flow during the irrigation season would be so regulated as to permit more nearly complete utilization for power during that period than is now possible. The release from storage during the winter of 1,000 second-feet would, however, provide a large power output during that period, and it is possible that water so released could be impounded in reservoirs below the power plants and thus conserved for irrigation during the following season.

If the American Falls reservoir were developed it would overflow a large area of bottom lands adjacent to the river, and the shore of the reservoir would be approximately indicated by the 4,400-foot contour line. The Indians would thus be deprived of a peculiarly valuable part of the reservation. After the development of the Fort Hall project, however, the Indians will be less dependent on the bottom lands for winter feed for their cattle, and a few years hence the reservoir might be constructed without serious disturbance of the economic relations of the Indians.

Blackfoot River.—If considered as a source of water power, the portion of Blackfoot River which forms the north boundary of the Fort Hall Reservation is divisible into three portions, as follows: (1) From its intersection with the east boundary of the reservation on the line between Rs. 38 and 39 E. to the mouth of the canyon near

the east line of sec. 11, T. 2 S., R. 37 E.; (2) from the mouth of the canyon to the upper diversion dam of the Fort Hall project; (3) from the upper diversion dam to the mouth.

The upper section is approximately 12 miles long. The total fall through this distance is about 800 feet, an average of approximately 67 feet to the mile. The existing surveys are not sufficiently detailed to show the distribution of this fall, but in some portions it appears to be fully 100 feet to the mile. Throughout this portion of its course the river flows through a deep narrow canyon, the rim of which is generally formed by a lava flow and the lower slopes by the talus from the lava cliffs. A view of the lower portion of the canyon showing its relation to Snake River valley is shown in Plate XII, *A*.

The second section is about 14 miles long. The total fall of the river is about 200 feet, or 15 feet per mile, and is quite uniformly distributed. The stream is bordered by agricultural lands throughout this stretch.

In the 10 miles that comprise the third section of the river the fall is small, only about 5 feet per mile. The banks are low and in many places are formed by sand bars and dunes.

The flow of Blackfoot River before it was regulated for irrigation by the construction of the Blackfoot River reservoir and the construction of diversion canals, ranged from a maximum of perhaps 2,500 second-feet early in the spring to a minimum of about 65 second-feet late in the summer. The minimum winter flow appears to have been about 100 second-feet. As regulated for irrigation, however, the regimen of the stream is materially changed. During the winter the flow of the river is greatly reduced by the impounding of water in the reservoir, but about 10 second-feet has been permitted to pass the dam during this period in order to save the fish in the river. The winter flow between the reservoir and the mouth of Sand Creek is thus confined to the small quantity permitted to pass the dam and the inflow of tributaries below the reservoir. Measurements of the flow of Corral and Grove creeks, which enter the river between the dam and the east line of the reservation, indicate that the minimum flow at the east line of the reservation will be approximately 30 second-feet. Wolverine Creek is fed by springs and has a minimum flow of about 13 second-feet. Cedar Creek and other small tributaries contribute about the same amount, so that the total flow at the mouth of the canyon will, under regulation for irrigation, be about 60 second-feet from the middle of October till the later part of March.

·igation season the flow will correspond approximately to ı demand, reaching a maximum of about 1,000 second- and averaging about 600 second-feet from about the to the first of October. Below the outlet of the Idaho

canal and above the head gate of the irrigation project the flow during the irrigation season may be further increased by the water brought through the canal from Snake River. The diversion of water at the head gate of the project will greatly reduce the flow below that point. Under present conditions the flow of Blackfoot River below the diversion point is as low as 50 second-feet during the irrigation season, and with the more complete development of the project it is probable that the summer flow will become negligible.

When the data above given relative to the discharge, slope, and topography of the river are considered together it becomes apparent that in the lower section of the river, below the head gates of the project, the development of water power is impracticable. In the middle section the character of the valley is such as to make the construction of dams impracticable, for a relatively low dam would cause the flooding of large areas of agricultural land. Such a dam would give opportunity for the development of only a small amount of power and the unit cost would be prohibitive.

In the upper section, however, in the canyon, certain conditions are somewhat more favorable to the development of power. Throughout the canyon the topography favors the construction of dams, the walls being in places nearly vertical (Pl. XII, *B*). At the mouth of the canyon a dam 100 feet in height would, according to La Rue, have a length of approximately 250 feet on the bottom and 350 feet on the top. Nothing is known, however, of the possibility of obtaining good foundations at this and at other similar sites through the canyon. With an effective head of 90 feet approximately 5,000 continuous horsepower can be developed at this site for about six months in the year and about 500 continuous horsepower during the remainder of the year. If a market could be developed for irrigation pumping or the plant were interconnected with other plants, it is probable that development at this site would prove feasible.

The lands adjacent to this portion of Blackfoot River have been reserved for the purpose of retaining control of the development of water power. The Secretary of the Interior is, however, authorized to give permission for such development on terms which he may regard as protecting the public interests.

Bannock Creek.—In its upper portion Bannock Creek has a rapid fall. The flow of the creek is well sustained throughout the summer, and late in the fall its total discharge is over 30 second-feet. As this flow is largely derived from springs it probably is not greatly reduced during the winter, although no winter measurements are available.

The most practicable plan of power development appears to be by conduit. If the water were diverted in the southern part of T. 9 S., R. 33 E., at an elevation of 5,015 feet and carried northward

the east side of the valley a distance of about 10 miles, a head of about 320 feet could be obtained at a power house located in sec. 22, T. 8 S., R. 33 E. The flow of the east and west forks of Bannock Creek, augmented by that of Rattlesnake, would probably warrant a conduit capacity of 35 second-feet. About 875 horsepower could be developed at a cost which preliminary estimates indicate would be very reasonable. This power development can be accomplished practically without interference with the development of irrigation in the Bannock Valley.

Below the point of return of this proposed power development the flow of the creek is largely diverted during the summer for irrigation. The slope is also much less, so that the lower portion of the creek affords no sites for power development.

Portneuf River.—In the upper portion of its course Portneuf River flows through a broad, marshy valley, with a slight fall. The discharge is small, and no feasible power sites are recognized in this portion of the river. After leaving Portneuf Valley the river has in many places a steady gradient and affords opportunity for the development of power, but none of these sites are within the reservation.

The lower portion of the river, west of Pocatello, has only a slight fall. The normal flow during the irrigation season is largely diverted for irrigation, and, as the Chesterfield reservoir of the Portneuf-Marsh Valley Irrigation Co. stores much of the winter flow the possibility of developing power on the lower portion of Portneuf River is unattractive.

Ross Fork.—On the North Fork of Ross Fork there is a small power site, where it is reported that a head of 284 feet can be obtained in a stretch along the stream of about 2 miles. The available flow is probably about 10 second-feet, except in times of extreme low water, and approximately 260 horsepower can be developed on the wheel shaft. This site has been considered by the Indian Service as a source of power for the buildings of the reservation headquarters. The lands which will be required for this development have been reserved.

Lincoln Creek.—Except in its headwaters, Lincoln Creek has only a moderate fall. The low-water flow is about 3 second-feet and sinks before it reaches Blackfoot River. The power possibilities of this stream are therefore unimportant.

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DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 714

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN

1919

BY

ALFRED H. BROOKS AND OTHERS

WASHINGTON
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1921

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ILLUSTRATIONS.

MINERAL RESOURCES OF ALASKA, 1919.

By ALFRED H. BROOKS and others.

PREFACE.

By ALFRED H. BROOKS.

This volume is the sixteenth of a series of annual bulletins[1] treating of the mining industry of Alaska and summarizing the results achieved during the year in the investigation of the mineral resources of the Territory. These reports are intended to give prompt publication of the more important economic results of the year. The time available for their preparation does not permit full office study of the field notes and specimens, and some of the statements made here may be subject to modification when the study has been completed. Those interested in any particular district should therefore procure a copy of the complete report on that district as soon as it is available.

This volume, like the others of the series, contains an account of the mining industry, including statistics of mineral production and also preliminary statements on investigations made by the Geological Survey. It is intended that this series of reports shall serve as convenient reference works on the mining industry for the years which they cover. It is not possible for a member of the Survey to visit every mining district each year, and therefore the information used in preparing the summary on mining development is in part obtained from other reliable sources.

During the war many members of the technical staff of the division of Alaskan mineral resources were called into the military service or employed in other war work. Owing to this transfer of personnel and because the Alaska investigations and surveys were not deemed to be directly important to the winning of the war, a reduction in the appropriation was made. Unfortunately the appropriation has not yet been restored to its prewar status. Meanwhile the cost of the field investigations has greatly increased. As a result many important

[1] The preceding volumes in this series are U. S. Geol. Survey Bulls. 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, 642, 662, 692, and 712.

surveys have had to be deferred, and this year's report is much smaller than those that have preceded it.

Again, as for many years in the past, the Geological Survey is under great obligation to residents of the Territory for valuable data. Those who have thus aided include the many mine operators who have made reports on production as well as developments. There are still some Alaskan mineral producers who fail to respond to requests for information. Many prospectors, Federal officials, engineers, and officers of transportation and commercial companies have contributed valuable data. It is impracticable to mention by name all who have aided in this work, but it should be stated that without the assistance of these public-spirited citizens the preparation of this report would have been impossible. Special acknowledgments should be made to the Director and other officers of the Mint; the officers of the Alaska customs service; the officers of the Alaskan Engineering Commission; the American Railway Express Co.; G. Howard Birch, of Nizina; F. E. Youngs, of Seward; R. N. Moyer and Sidney Anderson, of Anchorage; N. D. Bothwell, of the Willow Creek district; W. K. McLennan and R. E. Steel, of Chisana; John Elden, of Steel Creek; C. E. M. Cole, of Jack Wade; P. J. Hilliard, of Eagle; Charles Zielke, of Nenana; J. A. Fairborn, R. C. Wood, and the First National Bank, of Fairbanks; Charles Mayfield, of Richardson; Joshua L. Ray, of Healy River; M. T. Robinson, of Tofty; Alexander Mitchell, of Glen Creek, Kantishna; George W. Ledger, of Rampart; B. J. Bower, of Greenstone Creek, Ruby district; Herman Willeke, of Flat Creek, Ruby district; C. A. Boerner and C. E. Taylor, of Iditarod; Harry Madison, of Tolstoi; G. C. Glass and B. B. Smith, of Ophir; R. W. J. Reed and E. W. Quigley, of Nome; H. E. Carter, Thomas Aiken, and Charles Mespelt, of McGrath; William Loiselle and A. Stecker, of Kwinak; Lewis Lloyd, of Shungnak; George L. Stanley, of Kiana; and Volney Richmond, of the Northern Commercial Co.

THE FUTURE OF ALASKA MINING.

By Alfred H. Brooks.

OUTLINE.

The Alaska mining industry, which has turned out products having a total value of $438,160,000, began in 1880 with the recovery of some $20,000 worth of gold from placers near Juneau. Of this total value 96 per cent is to be credited to the gold and copper deposits, but Alaska mines have also produced silver, platinum, palladium, tin, lead, antimony, tungsten, chromite, coal, petroleum, marble, gypsum, graphite, and barite, and development work has been done on deposits carrying nickel, iron, molybdenite, and sulphur.

The exploitation of Alaska's mineral wealth before the war showed a rather steady growth, with some fluctuations from year to year, such as are more or less inherent to mining in remote regions. This advance was made in spite of the handicaps imposed by isolation, the inadequacy of means of communication, and the long existing interdict on the development of the coal and oil fields. Then came the change of industrial conditions wrought by the war. Its first effect was to increase Alaska's output of copper enormously, owing to the high price of that metal, and this increase in 1916 brought the value of the total mineral output of Alaska up to over $48,632,000, a larger amount than that for any other year since mining began. (See Pl. I.) The decline in price and market demand for copper since 1916 has greatly reduced Alaska's output of copper. Meanwhile the world-wide depression of the gold-mining industry has also greatly affected Alaska. As a consequence the value of the total mineral output of the Territory in 1919 was only $19,621,000, as compared with $28,254,000 in 1918, and was the lowest annual value since 1914.

This very marked decline of Alaska's mining industry has been noted with alarm by many who are interested in the Territory and has been especially disconcerting to the general public, because it came at a time when large Government funds were being expended on a railroad intended primarily to open up the mineral resources of the interior. This decline is not due primarily to local causes, however, but is largely the result of world-wide industrial conditions brought on both by the war and by the readjustments that have

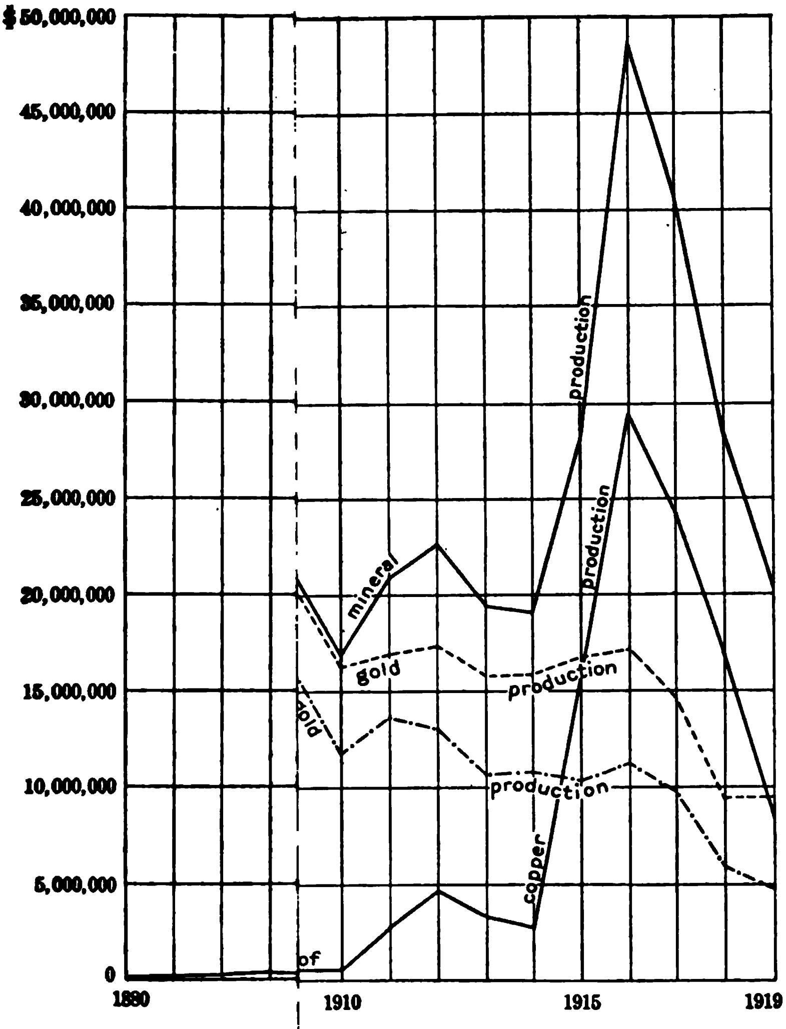
followed it. It is pertinent to inquire what the future holds forth for Alaska mining. If it is true that the decline in output is due to the general instability of industrial conditions recovery must await the improvement of these conditions. It would lead us too far afield to attempt here to discuss any of the broad problems connected with the present economic situation and its betterment. The purpose of this paper will be met by assuming that these conditions will improve.

Although many local factors affect the future of the Alaska mining industry, the most important consists of the mineral reserves. Unless the accessible reserves are large enough to support a future growth the mining industry, no matter how favorable may be the conditions of exploitation, will languish. Those who have inquired about the quantity of mineral reserves have usually received the stereotyped answer that Alaska has vast stores of mineral wealth awaiting development. However true this may be, the public has a right to know on what facts such statements are based. An attempt will be made here to summarize briefly these facts, which are scattered through scores of publications of the United States Geological Survey,[1] and to forecast, so far as may be, the future of Alaska as a producer of minerals.

Before considering the future of the mining industry, it will be desirable to examine briefly the record of the past as expressed by the value of the mineral output. The statistics of mineral production are given in a later section of this report (see pp. 59–76) and are expressed graphically by the accompanying diagram (Pl. I). On this diagram the value of the total mineral output and of the copper and gold is shown by curves, which give a measure of the mining industry for the last 40 years. The curves, though recording fluctuations from year to year, show on the average a rather uniform growth of output until the outbreak of the war in 1914, since when Alaska's mining industry has been unstable. If the pre-war curve showing the value of Alaska's total mineral output is projected over the last five years, it will indicate that under normal conditions the value would have been about $22,000,000 in 1919. It is significant that the actual value of the output in 1919 ($19,621,000) was only about 10 per cent below this normal value indicated by the curve. This in itself is very encouraging, for it indicates that the Alaska mines are on an average nearly holding their own, in spite of the present abnormally adverse conditions.

The pre-war curves might, of course, be projected also into the future, with a view of thus obtaining a rough estimate of the probable developments of the Alaska mines. Such an estimate would have little value, however, because the mineral output of the past does not

[1] A list of the principal publications of the Geological Survey relating to the geology and mineral resources of Alaska is appended to this volume.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indicate the changes that will be brought about by the construction of the railroad and wagon roads, the reduction in freight charges, and the opening of the oil and coal fields. Moreover, such an estimate would assume, without proof, that Alaska's mineral reserves are ample to support a growth of the mining industry in the future at the same rate as that of the past. The quantity of the several minerals occurring in Alaska is evidently the significant element in the problem. In discussing these reserves it will be desirable to limit the estimate to those which are now or can soon be made available.

An estimate of Alaska's mineral reserves would be difficult enough even with complete geologic maps of the entire Territory. Only about 20 per cent of Alaska has been covered by even reconnaissance geologic surveys, and less than 1 per cent by detailed surveys. This meagerness of geologic data is in a measure offset by the fact that the areas surveyed cover much of the immediately accessible parts of the Territory, where the most extensive mining developments of the near future are to be expected. The information at hand, however, at best does not permit quantitative estimates of reserves. Nevertheless, it indicates the areal distribution of the mineral deposits (Pl. II), and a study of their geologic occurrence gives a basis of forecasting their availability to the miner. These data, considered in connection with the accessibility of the deposits and the probable market for their output, will afford a rough measure of their availability in the near future.

GOLD MINING IN THE PAST.

During 40 years of mining Alaska has produced gold to the value of \$311,665,000, of which \$218,000,000 is to be credited to the placer mines. The first notable impetus given to gold mining in the Territory was the discovery of the Nome placers in 1898 and their rapid development, which reached its maximum in 1906. Meanwhile the placer gold from the Fairbanks district, first developed in 1903, helped to swell the gold output, into a maximum production in 1909. Much the larger part of the placer gold recovered in these two fields, as well as in most other placer districts, such as Iditarod, Hot Springs, and Koyukuk, has been taken from relatively small and very rich or so-called bonanza deposits rather than from larger bodies of gravel having a lower gold content. The production of placer gold in the past has therefore been maintained by the exploitation of new bonanzas rather than by larger installations in the developed districts. Since 1911, however, there has been a gradual improvement in mining methods, notably in the use of gold dredges, by which over \$20,000,000 worth of gold has been recovered.

Auriferous lodes in Alaska have yielded \$92,000,000 worth of gold, of which more than 80 per cent has come from the six large

low-grade mines of the Juneau district. Lode mining in the Juneau district rather steadily increased from the first large installation in 1887 to the depression that followed the outbreak of the war, which occurred at almost the same time as the wrecking of three of the Treadwell mines by an inflow of sea water. Successful lode mining at Juneau, in complete contrast to most of the placer operations, has been based on the exploitation of low-grade deposits on a very large scale. The mines have, indeed, been operated at a lower unit cost than any others in the world. The average value per ton of the gold and silver recovered from the ore produced in these mines since 1882 is $1.95. The small margin of profit was offset by the very large tonnage of ore handled. Because of the small margin these operations were naturally among the first to react to the economic conditions that have affected gold mining so adversely.

Most of the lode mines outside of the Juneau district have been small ventures that could practice none of the economies introduced at Juneau. Therefore, with the decline of mining at Juneau Alaska's auriferous lode-mining industry has received a serious setback.

To sum up, the production of placer gold has been founded principally on bonanza mining, while lode mining has been supported chiefly by the large-scale exploitation of low-grade ores. The tendency of bonanza mining has been to cause considerable fluctuations in the annual gold output, but these fluctuations have in a measure been offset by the steady production of the large Juneau mines.

The minor fluctuations in the annual gold output of Alaska are caused by the local mining conditions referred to above. There is, however, also a larger pulsation of this output, which is responsive to the general economic conditions, industrial, financial, and political, that affect the gold output of the entire world. The close parallelism between the gold output of Alaska and that of the world is shown in Plate III. This diagram shows that the larger oscillations of the world's gold production are clearly recognizable in the Alaska output, though Alaska at best has produced less than 5 per cent of the world's gold. This diagram also shows a tendency of the Alaskan gold output to lag a year or two in its adjustment to the general industrial conditions of the world. This delay is no doubt due to the isolation of many of the Alaska placer districts, which necessitates that preparations for mining be made a year or more in advance. The facts stated above show clearly that whatever local conditions may affect Alaska gold mining and however these may be improved by the construction of railways and roads and a betterment of the steamboat service, the progress of the industry is to a large extent controlled by factors that are world-wide in their effect. The gold miner now finds that, while his product commands

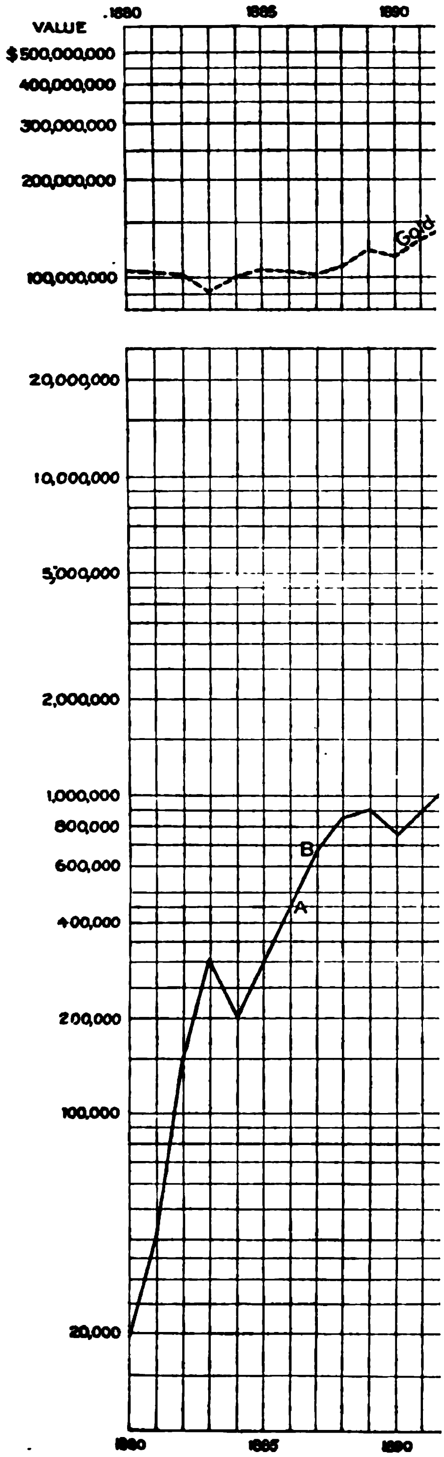

DIAGRAM SHOWING

The curves are l garithmic and therefore
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the same price as in the past, yet his costs, like those in all other industries, have enormously increased. For the purpose of this paper it will be assumed that these conditions will change, without discussing when or how this change will be brought about.

GOLD PLACERS.[1]

Auriferous gravels are very widely distributed over Alaska (see Pl. II, in pocket), but it is only in comparatively small areas that their gold content is high enough to permit profitable exploitation or, in other words, to constitute a placer. The question whether a body of auriferous gravels is a placer depends on the cost of its exploitation. If it can be exploited at a profit it is a placer, no matter how small its gold content. At one locality a body of gravel carrying less than 25 cents worth of gold to the cubic yard may be a placer, whereas at another a body of gravel whose gold content has a value of several dollars to the cubic yard may be worthless. Some of the conditions that affect mining costs, such as physical character and thickness of the deposit, grade of streams, and availability of water, are fixed. Others, relating chiefly to accessibility, may be improved by betterment of means of communication. Thus a body of gravel whose gold content is too low for profitable exploitation at one time may, with improvements in transportation, become a valuable placer.[2] In the early days of mining at Nome gravels that carried less than $5 in gold to the cubic yard could not be profitably exploited, but in 1918 the 21 dredges operating on Seward Peninsula made an average gold recovery per cubic yard of only 40 cents. Again, the average value of gold in all the gravel mined in Alaska in 1911 was $2.17 per cubic yard; in 1918 it was $1.20. This change has been due to a cheapening of mining cost, both by larger installations and by better means of communication. These facts of themselves make it impossible to estimate closely the reserves of the Alaska placers, even if the quantity and gold contents of the auriferous gravels were known, for it is impossible now to forecast what part of these gravels will in the future prove to be workable placers. On the assumption, however, that profitable mining will be possible in the future on the same grade of placers as it has in the past, a rough measure of the placer reserves can be arrived at.

A careful scrutiny of all the available geologic, statistical, and mining data indicates that the original total length of creek gravels that probably carry enough gold to be classed as placers is about 1,050 miles. Of this total, deposits aggregating about 200 miles are on creeks whose alluvial floors are 15 yards or less in width, and the

[1] The geologic features of some Alaska placers are set forth by A. H. Brooks in U. S. Geol. Survey Bull. 328, pp. 111-139, 1908.

[2] Brooks, A. H., The future of gold placer mining in Alaska: U. S. Geol. Survey Bull. 622, pp. 69-79, 1915.

rest on streams whose valley floors are chiefly from 50 to 100 yards wide, with some that have a width of 300 yards or more. In this total mileage have been included only those stream gravels which have been mined or more or less prospected. The many large deposits of gravels which are known to be auriferous but about whose gold content no information is available are not included in this estimate.

It is believed that of this 1,050 miles of original gold placer ground, 250 miles has been mined out. The value of the total placer-gold output of Alaska is $218,000,000, of which about $18,000,000 is to be credited to beach and high bench placers that are not included in this estimate of stream gravels. Therefore, as nearly as can be determined, the stream gravel placers thus far exploited have yielded gold to the value of $800,000 to the mile. Much of the placer gold has been won from bonanza deposits, such as those of Nome, Fairbanks, and Hot Springs. The Fairbanks placers have produced about $2,000,000 worth of gold to the mile for the ground actually mined, and the recovery from the creek placers of the Seward Peninsula[3] has been about $500,000 to the mile. On the other hand, the recovery has been only $50,000 to the mile in some of the poorer districts.

Although it is quite possible that other very rich creek placers will be found in Alaska, notably in the Yukon and Kuskokwim basins, where there are many streams that have not yet been thoroughly prospected, yet a forecast of the future can not take account of such possible discoveries, and must include in the estimate of available reserves only placers about whose gold content there is some information based on actual development. If the gold-placer reserves are measured by the least valuable creek placers that have thus far been developed, namely, at $50,000 a mile, the total value will be $40,000,000; if the estimate is based on the average gold recovery of the past, the total value will be $640,000,000. The truth will lie somewhere between these two extremes. In the writer's opinion it will be conservative to estimate the value of the undeveloped creek placers at $200,000 a mile, a figure which will make the value of the total creek placer reserves $160,000,000. To these must be added the reserves of bench and ancient beach and gravel placers. Deposits of these types have been developed and tested only on Seward Peninsula. It was estimated some years ago that the value of the gold reserves in the gravel-plain, ancient-beach, and high-bench placers of Seward Peninsula was about $215,000,000.[4] Subtracting the amount of gold that has since been mined from these deposits leaves the value of the reserve $200,000,000. This very large reserve compared with those of other parts of Alaska is due largely to the fact that in Seward Peninsula the cost of mining has been much lower

[3] The richest ground in Seward Peninsula has been in the beach and high bench placers.

[4] Brooks, A. H., U. S. Geol. Survey Bull. 328, pp. 135-138, 1908.

than elsewhere in Alaska. Therefore deposits of a low gold tenor are included in the reserve.

Though the above estimates of available placer gold reserves may appear extravagant to some, a comparison will show that they are moderate. Recently a committee of experienced Fairbanks mine operators under the leadership of John A. Davis, of the Bureau of Mines, collected all available information on the dredging ground of the Fairbanks district. This information was carefully checked by Mr. Davis, and as a result it was estimated that the dredging ground on the creeks immediately tributary to Fairbanks includes a total of 218,000,000 cubic yards, with an average gold content of about 46 cents to the cubic yard and a total reserve of gold of the value of \$100,200,000.[b] During the 17 years of mining at Fairbanks some \$70,000,000 worth of placer gold has been mined out, yet there still remains in the ground, according to a conservative estimate, over \$100,000,000 worth of gold.

In view of the above facts it is believed that the available placer-gold reserves in the developed districts of Alaska have a value of at least \$360,000,000 and perhaps of twice that amount. There is also the possibility of discoveries of new deposits, of which not even a rough estimate can be made.

GOLD LODES.

Few of the Alaska gold-lode mines have blocked out ore to supply them for more than a few years in advance, and therefore there is no basis for estimating their reserves, which are developed from year to year. The large Juneau mines, where development work has usually been kept well in advance of the stoping, can for the present not be counted as a very definite source of gold. Most of the other auriferous lode mines are equipped with only small plants. Many of them are, indeed, only prospects with small mills, operated for only a part of the year. Were the future of Alaska's gold-lode mining dependent on the developed mines, the outlook would not be hopeful.

In the absence of developed ore bodies the future of lode mining must be gaged by considerations of the geologic occurrence and distribution of the ores. Such facts can not be interpreted in terms of reserve tonnage, yet they will serve to indicate the probability of discoveries.

The wide distribution of gold placers is in itself an indication of widespread mineralization. Gold placers by no means give definite evidence that the gold is sufficiently concentrated in its bedrock source to be profitably mined. Yet the placers show that the bedrock is mineralized, and this fact alone augurs well for the discovery

[b] Construction of Alaska Railroad: 66th Cong., 1st sess., Hearings before the House Committee on Territories on H. R. 7417, July 23, 24, 25, and 31, 1919, p. 142.

of auriferous veins. Moreover, some auriferous quartz veins have been found in nearly every placer district. (See Pl. II, in pocket.) The geology shows that the Alaska auriferous quartz is genetically related to intrusive granitic and kindred rocks.[a] Such intrusive rocks are widespread in the territory south of the crest of the Arctic Mountain system. The geologic conditions are therefore favorable to the occurrence of auriferous quartz veins. This fact has been generally recognized, and the question is often asked why more lode mines have not been developed. A partial answer to this question lies in the fact that in much of Alaska lode prospecting is beset by the difficulty that the bedrock is masked by a mat of moss and other vegetation. Therefore the lode prospector has little to guide his search except the distribution of placer gold. Moreover, there has been little incentive to lode prospecting. The inaccessibility of so much of Alaska has prohibited mining development except such as could be carried on with the simple tools and methods of the placer miner. Much of the placer mining has been done far from navigable rivers, where there were no roads and few, if any, trails. Under such conditions lode mining can not thrive.

On the other hand, where a region has been made even reasonably accessible small lode-mining industries have sprung up, as, for example, in the Willow Creek and Fairbanks districts. The evidence in hand indicates that gold-lode mining in Alaska has only begun, for there are many districts that contain evidence of the presence of auriferous veins. Though no quantitative statement of reserves of lode gold is possible, there can be little doubt that when normal economic conditions become reestablished and transportation is provided, lode mining will be undertaken in many localities. It is quite possible that the reserve of lode gold far exceeds that of the placers.

COPPER.

GENERAL FEATURES.

The total copper production of Alaska to the end of 1919 has been 545,007,336 pounds, recovered from 3,736,000 tons of ore. The first copper-mine developments were in the Ketchikan district, but production began in 1900 in both the Ketchikan and Prince William Sound districts. The first large shipments of copper ore from the great Kennecott mine, in the Chitina district, were made in 1911, after the completion of the Copper River Railroad. At about the same time the Beatson-Bonanza mine, on Latouche Island, in the Prince William Sound region, was opened on a large scale. In 1913 the Jumbo and Mother Lode mines of the Kennecott group began shipping ore. These two, together with the original Kennecott mine,

[a] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, pp. 43–74, 1911.

are operated on very rich chalcocite ore, and it is their output which has so greatly swelled the copper output of Alaska. It was a fortunate coincidence that these rich mines should have been prepared to take advantage of the war prices of copper. The large output of

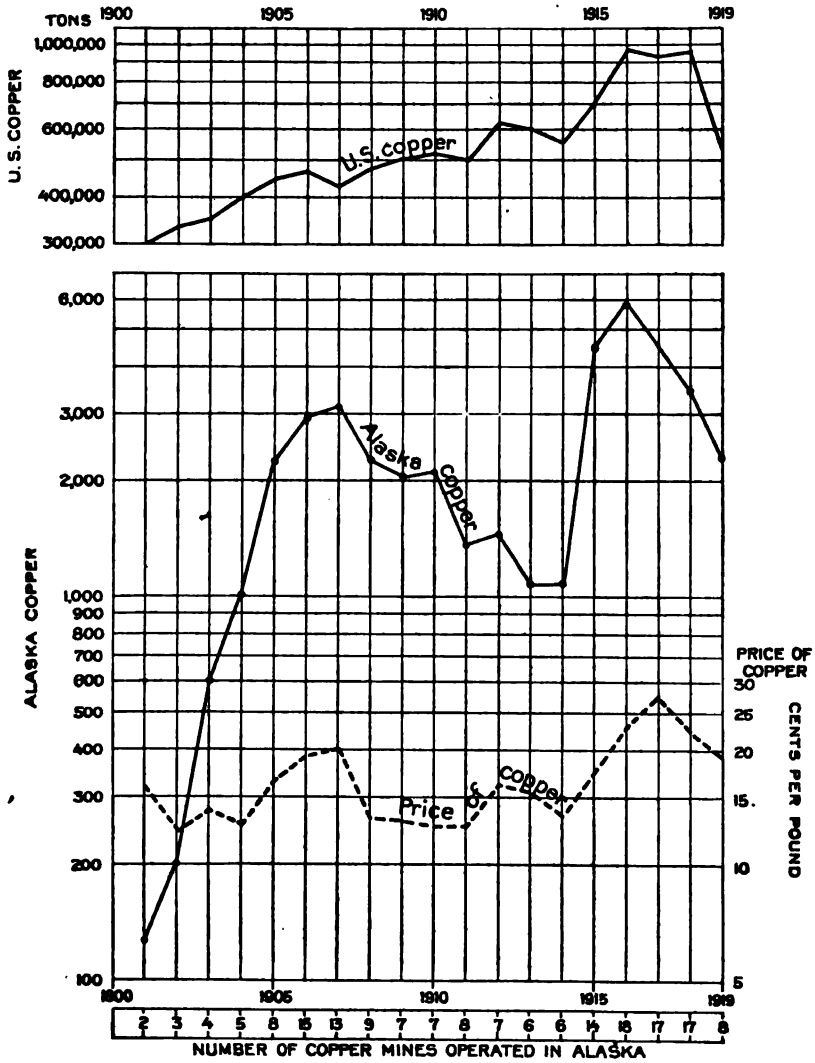

FIGURE 1.—Diagram showing progress of Alaska copper-mining industry. The curves are logarithmic and therefore may be directly compared with respect to rate of increase or decrease. The same slope indicates the same rate of change, irrespective of the quantities involved.

copper ore from these three bonanza deposits has greatly benefited the industries of Alaska and has stimulated other copper-mining ventures. The Beatson-Bonanza, the only other large copper mine in Alaska, is working a large body of copper ore of much lower grade than that of the Kennecott group. This ore is concentrated by oil flotation before

shipment. Most of the other copper mines are small, and many are developing ore bodies which are not large and whose copper content is low. As a consequence of this condition and of high freight rates, many of the small mines have been operated only during the period of high price for copper. This fact is illustrated by the accompanying diagram (fig. 1). Even during the periods of high prices, especially during the war, lack of shipping or refusal of smelters to take the ore has prevented the operations of some small mines. As a consequence, there is general discouragement among the small producers, and their number is decreasing.

The history of the Alaska copper-mining industry is well illustrated by figure 1. This diagram shows the annual Alaska copper production, as well as the price of copper and the number of mines operated. For the sake of comparison the curve of the annual copper output of the United States is added. A comparison of the copper production of Alaska and that of the United States shows that the former represents an unstabilized industry. Although its larger fluctuations harmonize with those of the output of the United States, yet its pulsations very closely accord with changes in the price of copper. The production of copper in Alaska has in general been greatly on the ascendancy during the last decade, yet this rise must be credited to the mining of the very rich ores of the Kennecott group. No one can predict how long this bonanza copper mining will continue, but it probably can not be counted upon to support a permanent industry. For example, had there been no mining in the Kennecott group during 1919, only one large and four small producing copper mines would have been operating in all Alaska, Though there is no reason to believe that for the present Alaska's copper production will decline, except in so far as it is affected by world-wide industrial conditions, yet it is not to be expected that a large and growing permanent industry can be based on the present developments. In spite of these conditions the outlook for a larger copper production from Alaska in the years to come is very favorable. Though the tonnage of ore actually developed is small, the distribution or copper deposits is very wide. (See Pl. II, in pocket.)

In view of the importance of the copper resources of Alaska and of the considerable variety in their occurrence, they will here be considered in greater detail than those of the other valuable minerals. The geologic aspect of the subject, notably the genesis of the deposits, will receive only brief mention. This matter is more fully discussed in the many publications cited, which also contain descriptions of individual deposits.

That part of the geologic history bearing on possible enrichment of the copper deposits, however, deserves special mention. Most of the Alaska copper districts have been profoundly glaciated in recent

times, and as a result the zone of surface oxidation and enrichment has been removed. Postglacial time has been too short to permit the formation of any deep zone of oxidation. Grant and Higgins have suggested the possibility that some of the chalcopyrite deposits of the Prince William Sound may have been enriched during preglacial time.[7] Neither the facts revealed by mining operations of the decade that has elapsed since the Grant and Higgins survey was made nor the detailed geologic investigations by B. L. Johnson in this province have given any support to this suggestion, which was only tentatively advanced by its authors. All the evidence points to the conclusion that these sulphide minerals are primary. The same is true of the copper sulphides of the Ketchikan district. Bateman and McLaughlin, in an exhaustive study of the Kennecott ore bodies, hold that although the evidence is not entirely conclusive, yet it points to the conclusion that these chalcocite ores are primary.[8]

The sulphide copper deposits of the Susitna, Iliamna, and Nabesna-White River districts all occur in glaciated regions. Little underground work has been done on these deposits, but their mineral character and geologic occurrence indicate that their ores are also primary. It may be added that this is in general also true of Alaska ores other than copper. Exceptions are to be looked for in the unglaciated regions, however, notably in the Yukon and Kuskokwim basins and on Seward Peninsula. In these regions there has been as yet no deep mining, so that positive evidence of a change in tenor with increasing depth is lacking. In places, however, some evidence of a deep zone of surface oxidation has been found. As the surface material is in general permanently frozen, this oxidation must have taken place before the formation of the permanent ground frost; and as the permanent ground frost is a survivor of the glacial climate of the past, this oxidation was preglacial.

The practical deduction from these facts is that no greater variation in the mineral composition and copper content of the Alaska ores is to be expected at depths to be reached by future mining than has already been noted within a few feet of the surface. This is true of all the important Alaska copper districts thus far discovered, but possibly it does not hold for ore deposits which may occur in the unglaciated or only slightly glaciated regions, such as the Yukon and Kuskokwim basins and Seward Peninsula.

THE DEPOSITS, BY DISTRICTS.

SOUTHEASTERN ALASKA.

All the productive copper mines as well as the largest developed cupriferous ore bodies of southeastern Alaska are in the Ketchikan

[7] Grant, U. S., and Higgins, D. F. Reconnaissance of the geology and mineral resources of Prince William Sound: U. S. Geol. Survey Bull. 443, pp. 58-60, 1910.

[8] Bateman, A. M., and McLaughlin, D. H., Geology of the ore deposits of Kennecott, Alaska: Econ. Geology, vol. 15, pp. 66-80, 1920.

district.[a] Copper is widely distributed in the Ketchikan district and, as will be shown, occurs in deposits of several distinct types. The most important so far as present production and extent of proved ore bodies are concerned are the contact deposits, which have yielded more than 98 per cent of the copper produced in the Ketchikan district.

The largest of the developed contact lodes are essentially chalcopyrite-magnetite deposits. Others which are less common consist mainly of chalcopyrite and pyrrhotite. All the ores carry pyrite, molybdenite, and specularite as accessory minerals. Some of the ores contain small amounts of nickel and traces of cobalt. The ores that have been mined carry enough gold to increase their value materially. In some localities a shallow surface zone of copper carbonates and other secondary minerals has been formed, but these deposits are not large enough to be of commercial importance.

These deposits occur in or near the contact-metamorphic zone caused by the intrusion of granitic and dioritic material into the sedimentary rocks among which limestone predominated. Such deposits have also been found in the contact zone of schists, greenstone tuffs, and graywackes.

The gangue of the contact deposits consists principally of minerals resulting from the alteration of the country rock and includes garnet, epidote, pyroxene, amphibole, and calcite. Calcite is sufficiently abundant in some of the ores to give them special value as flux. Quartz also occurs in all the deposits, but it is usually not abundant.

The typical contact deposits are masses of irregular outline, and some have very poorly defined boundaries. In some places a little copper occurs in zones about 200 feet wide, but the ores thus far mined have been taken from the smaller and much richer shoots, which are irregularly distributed through the contact rock or the larger bodies of low-grade ore. One difficulty that has beset the miner is the great irregularity in occurrence of the rich ore shoots. It is not uncommon to find an ore body whose horizontal cross section is almost square and which ends abruptly at the bottom. In many places search will reveal another ore shoot at greater depth. Hence there is little guide to the search for ore except the zone of contact metamorphism. The largest deposits thus far developed consist

[a] The copper deposits of the Ketchikan district are described in the following publications:

Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, 1908.

Wright, C. W., Geology and ore deposits of the Copper Mountain and Kasaan Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 87, 1915.

Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, pp. 83-100, 1916.

Smith, P. S., Lode mining in the Ketchikan district: U. S. Geol. Survey Bull. 592, pp. 75-94, 1914.

Chapin, Theodore, Mining developments in the Ketchikan and Wrangell districts: U. S. Geol. Survey Bull. 662, pp. 63-75, 1918.

of huge bodies of magnetite in which chalcopyrite occurs both finely disseminated and in shoots of massive sulphides.

Incidentally to the search for rich ore shoots, which are as yet the principal source of the copper produced, a considerable tonnage of concentrating ore has been blocked out. There are also much larger bodies of low-grade ore which contain too little copper to be now classed as commercial ores. The reserves of such ore have not been determined, and little is known of their average copper content. It is probably true, however, that if a magnetite ore carrying 0.5 per cent copper could be utilized (see p. 41), the developed reserves would be very large; also that the hope of finding other similar deposits is well founded.

Among the best examples of the contact copper deposits in the Ketchikan district are those at the Mount Andrew, Mamie, Poorman, and It mines, on Kasaan Peninsula; the Rush & Brown mines, on Karta Bay; and the Jumbo and Copper Mountain mines, on the west side of Prince of Wales Island.

Another type of the copper deposits of the Ketchikan district is represented by those occurring in cavities formed by shear zones. Though these deposits appear to be largely cavity fillings, there is evidence in some places that they are in part formed by replacement of the country rock. The principal metallic minerals of the shear-zone deposits are chalcopyrite and pyrite, but they also contain some magnetite, pyrrhotite, sphalerite, and galena, as well as some gold and silver. Country rock, quartz, and calcite form the gangue of these deposits. The shear-zone deposits follow zones of fracture that are parallel to the schistosity of the country rock. They are found in various kinds of country rock but primarily in greenstone schist, graywacke, and sheared diorite.

There are two phases of the shear-zone deposits. One consists of lenses or tabular deposits, many of which are made up largely of rich massive sulphide minerals. These have well-defined walls and are not unlike the cupriferous quartz veins described below. The other phase consists of disseminated deposits in which the sulphides are distributed through wide zones of sheared country rock, generally without well-defined walls. In some of the disseminated deposits the sulphide mineralization is rather evenly distributed through the entire mass, which may thus be a large body of low-grade ore. More commonly, however, the mineralization is concentrated along certain zones determined by the intensity of the shearing. In some of the deposits there has been marked silicification over a considerable width, but the sulphide minerals occur chiefly in ore shoots and stringer leads limited to certain parts of the whole mass. Practically all these disseminated deposits include ore shoots in irregular and tabular masses, and some are of sufficient

size to form commercial ore bodies, as defined by the methods of mining and recovery that have existed in the past.

Up to the present time mining of the copper ore in shear zones has been confined to the lenses and tabular masses occurring either as separate deposits or as a part of the lower grade disseminated ore bodies. The larger bodies of low-grade disseminated ore have received relatively little attention, and little is known of their copper content. It will require much prospecting and careful sampling to determine whether they are of commercial importance.

Examples of the shear-zone deposits, including both the concentrated and disseminated phases, are found at the Rush & Brown mines, on Karta Bay; at Niblack Anchorage and McLean Arm, on the east side of Prince of Wales Island; at the Corwin and Red Wing properties, near Hetta Inlet, and on Big Harbor (Trocadero Inlet), on the west side of Prince of Wales Island; and on McLeod Bay, Dall Island.

There are also in the Ketchikan district some copper-bearing quartz veins and brecciated zones. The deposits of this type thus far developed are small and have been exploited chiefly because of their silica content. They are essentially chalcopyrite-bearing quartz veins but contain also pyrite, sphalerite, tetrahedrite, and galena. All carry gold and silver. In some the gangue includes calcite and barite. These veins occupy true fissures with well-defined walls and cut both sedimentary and igneous country rock. In some the sulphides are well disseminated, but more commonly they occur in massive shoots separated by more or less barren vein matter. Chalcopyrite-bearing quartz veins are found in many places in the Ketchikan district, but most of them are too small to warrant development. The largest developments on this type of deposit are at the Cimru property, on the north arm of Moira Sound, and at the south end of Gravina Island.

One other type of copper deposit in the Ketchikan district deserves mention, even though as yet only one example of it has been developed. This occurs in pyroxenite with gabbroic phases and appears to have been deposited in a very irregular zone of fracture. It carries bornite, chalcopyrite, and metals of the platinum group, chiefly palladium. The gangue is practically all country rock. This deposit, on which the Salt Chuck mine is located, was first opened as a low-grade copper deposit but its present importance is due to its content of palladium and platinum. (See p. 38.)

It has been shown that the best developed of the Ketchikan copper deposits are those composed essentially of chalcopyrite, magnet-te, and pyrite. Some of these have a considerable percentage of ime. Much of the successful mining of the past has been done ecause of the smelter demand for base ores and the premium paid

for a high iron content. The change in metallurgic practice has decreased this demand, producing an adverse effect on copper mining in the district. Limestone is abundant in southeastern Alaska.[10]

The Ketchikan copper deposits are not far from tidewater and are on good harbors open to navigation throughout the year. They are connected by sheltered waterways with the smelters at Anyox, Tyee, and Tacoma. This condition should give cheap freight rates. The strong topographic relief, excellent timber, and good water powers of the district all favor low mining costs.[11]

A total of 543,498 tons of copper ore has been produced in the Ketchikan district since mining began in 1901. This ore yielded 34,056,376 pounds of copper, gold to the value of $545,000, and 255,440 ounces of silver. The average copper content of this ore is 62.66 pounds to the ton, equal to 3.13 per cent. The average value of the gold and silver content is $1.31 a ton. The average value of the total metallic contents of the ore is $12.71 a ton. No attempt has been made to concentrate the Ketchikan ore except by hand sorting.[11a] The small mines have normally maintained their shipping grade of ore at 5 per cent or more.

The facts above set forth clearly indicate that the Ketchikan district contains copper deposits which are well worth investigating by those who have the capital to develop and reduce ores on a large scale. The physical conditions seem almost ideal for cheap operations. Special attention should be directed to devising methods by which the iron content of the chalcopyrite-magnetite ores, as well as the copper, can be utilized.

Some work has been done on copper deposits on Kupreanof and Woewodski islands, in the Wrangell district, adjoining the Ketchikan district on the north. These deposits are chiefly chalcopyrite-bearing quartz veins.[12] Copper has also been found in a shear-zone deposit on William Henry Bay, an indentation on the west side of Lynn Canal. (See p. 108.) There are also some copper deposits associated with greenstones on Glacier Bay. The occurrence of a nickel-bearing copper ore in the Sitka district is noted below. (See p. 40.)

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[10] Burchard, E. F., Marble resources of southeastern Alaska: U. S. Geol. Survey Bull. 682, 1920.

[11] The Granby Consolidated Mining, Smelting & Power Co. reports that in 1916-17 the cost per ton of ore produced, "including development and waste," at the Mamie mine was $3.733 (production 20,115 tons) and at the It mine $5.54 (production 14,881 tons). This included the cost of much diamond drilling on both properties. (See report of company for year ending June 30, 1917, p. 20.)

[11a] The palladium-copper ores of the Salt Chuck mine are concentrated by oil flotation.

[12] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 140-142, 1908.

Chapin, Theodore, Mining developments in the Ketchikan and Wrangell mining districts: U. S. Geol. Survey Bull. 662, pp. 73-74, 1918.

PRINCE WILLIAM SOUND.

Copper in the form of sulphides is very widely distributed on Prince William Sound, but as yet commercial ore bodies of this metal have been developed at relatively few localities. Though some shipments of copper ore have been made from a dozen different properties, only three large mines have been opened. Most of the mining has been done by those who had little capital and hence were forced to concentrate their efforts on the search for rich ore shoots that would promise immediate returns rather than on the prospecting of the larger ore bodies of lesser copper tenor, on which a more permanent industry could be established. As a consequence the present developments have not aided much in determining the potential value of the copper deposits of the region as a whole.

The following brief summary is based chiefly on the published reports dealing with the mineral resources of the region, especially those by B. L. Johnson, supplemented by some personal observations of the writer. Information regarding the copper deposits of Prince William Sound is contained in the following publications of the Geological Survey:

Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: Bull. 443, 1910.

Capps, S. R., and Johnson, B. L., The Ellamar district, Alaska: Bull. 605, 1915.

Johnson, B. L., The Port Wells gold-lode district: Bull. 592, pp. 195–236, 1914.

Johnson, B. L., Mining on Prince William Sound: Bull. 592, pp. 237–244, 1914; Bull. 622, pp. 131–139, 1915; Bull. 642, pp. 137–145, 1916; Bull. 662, pp. 183–192, 1917; Bull. 692, pp. 143–151, 1919.

Johnson, B. L., Copper deposits of the Latouche and Knight Island districts, Prince William Sound: Bull. 662, pp. 193–220, 1917.

Johnson, B. L., Mineral resources of Jack Bay district and vicinity, Prince William Sound: Bull. 692, pp. 153–173, 1919.

Copper has two essentially different modes of occurrence in this region. Chalcopyrite is found in many of the auriferous quartz veins but principally as an accessory mineral. It may occur in sufficient quantity in some of these veins to form a low-grade siliceous copper ore. These auriferous quartz veins are widely distributed on the sound, but the most valuable thus far developed are in the Valdez and Port Wells districts. Many occur in close association with intrusive granites, and a genetic relation of these veins to granites is fairly well established. The chalcopyrite-bearing quartz veins have not been mined for their copper content.

The only copper deposits that are as yet of commercial importance on the sound are those in shear zones. These deposits are confined to the regions where greenstones are present, and their genetic relation to the greenstones is therefore probable. The greenstones are chiefly ancient lavas, principally diabase. In places the greenstones include tuffs, and locally they are altered by shearing into greenstone schists,

Some of the greenstones are intrusive sills, stocks, and dikes. Greenstones are rather widely distributed on the sound but are especially abundant near Cordova, in the Ellamar district, on Knight Island, and in the Columbia Glacier region. Though the copper lodes appear to be limited to the districts where greenstones are found, the largest deposits thus far developed are in the sediments and not in the greenstones.

The commercial bodies of copper ore on the sound as now known are essentially cavity fillings in zones of shearing and brecciation. There has also been some replacement of the country rock by mineral-bearing solutions, especially in the deposits occurring in some of the slates, which are more or less calcareous.

So far as now determined two conditions appear to be essential for the occurrence of copper ores in this region. One is the presence of greenstones, either as the country rock or in the vicinity of the deposit, and the other is the occurrence of shear zones of considerable magnitude. Sulphide mineralization is very common along planes of movement in the rocks of the sound, especially in the greenstone. It is only in the exceptional localities where the zone of shearing and brecciation has sufficient width that ore bodies can be expected. Evidently the minimum width of a shear zone that can be profitably mined depends on the grade of the ore it contains. Thus rich ore bodies only 4 to 10 feet wide have been profitably exploited. The future of the district, however, depends on the development of low-grade disseminated deposits. Such an ore body is being worked at the Beatson-Bonanza mine, on Latouche Island, where the zone of crushing and shearing is several hundred feet wide.

The shear zones in which the ore bodies occur were formed during a period of crustal disturbance that affected the entire province. These rock movements were intensified in certain localities that presented favorable conditions to the formation of ore bodies. It appears that the loci of intense movements were largely controlled by the physical character of the country rock. Among the diversified formations of the sound there were certain zones that were less resistant to movement than others, and here the largest shear zones were formed. The greenstones, for example, presented few lines of weakness, and in those rocks the movement was taken up by many fractures more or less generally distributed through the whole rock mass. Thus in the great greenstone masses of Knight Island there are innumerable fractures, many of which contain sulphides.

Many of the narrow shear zones, in which the mineralization is practically confined to a single fault plane, and may be traceable only a very short distance, have been accepted by the prospector as evidence of the presence of ore bodies. As a result many valueless claims have been staked and much useless development work has been done.

Much of this futile expenditure of time could have been avoided by obtaining a reliable sample by means of a short open cut.

In general it is true that the massive greenstone is not favorable for the development of wide shear zones, but exceptionally shear zones may be developed along a line of weakness presented by the contact of two ancient lava flows, as appears to have occurred at Rhea Cove, Knight Island. Tuffaceous beds within the greenstone, as on Orca Bay, may afford favorable conditions for the formation of shear zones. In other localities, as at Landlocked Bay, the presence of beds of slate within the greenstone may afford loci of weakness where shear zones are likely to be developed.

Among the sediments of Prince William Sound, which are chiefly graywacke and slates, the largest shear zones are within the weakest rocks. The slates are particularly favorable to shearing movements and hence to the formation of mineralized shear zones. Examples of this type of deposit are found at Ellamar, at the Midas mine, near Valdez, and at Horseshoe Bay, on Knight Island. Some of the deposits in the slates have a strikingly lenticular form, probably because they have replaced calcareous lenses in the slate. The Ellamar and Horseshoe Bay ore bodies are examples of this type.

In other localities the shear zones are developed along interbedded slates and graywackes. In these zones the slates are more intensely crushed and mineralized than the graywackes. The Beatson-Bonanza ore body, the largest thus far developed, is an example of this form of deposit. A similar deposit, adjacent to it on the north, is that of the Girdwood mine. Other examples of this mode of occurrence are at the Shlosser, the McIntosh, and the Mason & Gleason mines, near Fidalgo Bay.

One other fact in regard to the localization of considerable shear zones deserves mention. The shearing seems especially pronounced where weaker strata have been crushed against a hard, resistant rock mass. Thus, at the Beatson-Bonanza and Girdwood mines the slates and thin-bedded graywackes have been crushed against the massive footwall graywacke. The Midas ore body is in slate, folded against hard graywacke. At Fidalgo Bay massive graywackes are in juxtaposition to the mineralized shear zones developed along weaker rocks. At Ellamar and Landlocked Bay the mineralized shear zones lie along the margin of a mass of resistant greenstone. It appears, therefore, that where weaker rocks were buttressed against resistant masses the shearing was intense and probably deep-reaching openings were formed along which mineralizing agents could find passage, and the crushed rock was favorable to replacement.

The ore bodies are all of the same general form, with the exception of the lenticular deposits in the calcareous slates, already noted. Within the shear zones the most intense crushing or brecciation

follows certain beds, usually the softest rock. Thus, in the deposits occurring in graywacke and slates, the slates are the most intensely crushed and mineralized. Thin-bedded graywackes may also be crushed and impregnated with sulphides, but heavier beds will be but little altered and may form horses in the deposit. The factors that control the distribution of mineralization in the greenstone are less evident. Here, too, the most intense mineralization is concentrated along certain zones. In addition the more massive parts of the shear zone may be impregnated by the sulphides, but each ore body includes horses of unaltered country rock. It appears that the ore bodies in the slate show less variation in their sulphide content.

Practically all the deposits contain rich ore shoots, of which many are made up of solid sulphides, irregularly distributed through the larger deposit of lower-grade ore. It is these rich shoots which have been sought for and mined by the smaller operators. The ore bodies upon which large-scale mining must be based are disseminated deposits of low copper tenor.[12a] Many deposits, notably those in the greenstone, have no well-defined walls, and their limits will be set by the minimum copper content that can be profitably recovered.

The shear-zone deposits do not differ greatly in their mineral composition, the variations being chiefly in the relative proportion of a few sulphides. Chalcopyrite is in most places the dominating copper mineral, though some deposits carry a large percentage of the less valuable chalmersite. Pyrite is present in all the deposits in large quantities, but the percentage of pyrrhotite varies considerably. Some of the deposits are essentially bodies of pyrite carrying more or less chalcopyrite (Horseshoe Bay). Another type is one in which pyrrhotite carrying disseminated chalcopyrite is the dominating mineral (Rhea Cove). Most of the ores contain sphalerite and galena as accessory minerals and some arsenopyrite. There is a little gold and silver in most of the deposits, and in some the gold amounts to several dollars a ton.

As the country rock in these shear-zone deposits is ground up and intimately mixed with the sulphides, it constitutes the principal part of the gangue. Exceptions to this rule were found in some of the deposits occurring in slate, where the zone of fracture is cleaner and there is less country rock included in the ore. This is notably true of some of the lenticular deposits. Both quartz and calcite occur as gangue minerals, as do also in less abundance chlorite and epidote. In many of the rich ore shoots there is but little gangue.

As a rule the ores are base, with a high percentage of iron. The copper-bearing auriferous quartz veins have not been developed except for their gold content, but form a possible source of siliceous

[12a] The ore mined at the Beatson-Bonanza mine in 1919 had an average copper content of 1.95 per cent (Kennecott Copper Corp. Fifth Ann. Rept., 1919, p. 5, New York, 1920).

ores. There is practically no limestone on Prince William Sound, but limestone is abundant in the tributary Copper River valley and also occurs at tidewater near Seldovia, on Cook Inlet.[13]

A little work has been done on the copper deposits near Cordova, which are in some respects different from the normal type. These occur along shear zones in a greenstone bedrock, which is in part an amygdaloidal basalt. They differ from the deposits described in containing considerable bornite as well as some native copper, with a gangue of quartz, calcite, and epidote. The native copper is probably secondary.

The geology of the deposits above described shows that the conditions which lead to the formation of ore bodies are not complex. There is good reason to believe that they have occurred also in localities not yet thoroughly explored underground. Therefore the outlook is favorable for finding other ore bodies of equal value to those already opened.

The first mining on Prince William Sound was done in 1900, and since then a total of 1,819,578 tons of ore has been produced, from which 94,185,716 pounds of copper, $1,099,176 worth of gold,[14] and 772,749 ounces of silver have been recovered. The average copper content of the ore mined was 51.76 pounds to the ton, or 2.58 per cent. On an average 60 cents' worth of gold and 0.43 ounce of silver were obtained from each ton of copper ore. This average gold value is somewhat misleading, because much the larger part of the ore contains only an insignificant amount of gold. The average has been greatly increased by the high gold content found in part of the Ellamar ore body. The average value of the total metallic contents of the copper ores produced on Prince William Sound during 20 years of mining is $11.32 a ton.

Much the larger part of the above-stated tonnage is the output of the Beatson-Bonanza mine, where the ores are concentrated by oil flotation. No other attempts have been made to concentrate the Prince William Sound ores, but a mill is in course of erection at the Girdwood mine. Only high-grade ores have been shipped by the small mines, where the attempt has been made to keep the grade up to 8 or 10 per cent. This is done by mining only the richer ore shoots and by hand sorting the shipping ore.

Nearly all the copper deposits of this region are readily accessible from tidewater, and the ore can usually be delivered at the beach by aerial trams. It is transported to the smelters of Washington and British Columbia by ocean routes open to navigation throughout the year. Given tonnage enough to justify the employment of

[13] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 111-112, 1915.

[14] This of course does not include the gold recovered from the auriferous quartz veins of the Sound.

suitable carriers, freight rates should not be high. On the other hand, should a sufficient tonnage be developed and local smelting of the ores prove to be economical, the necessary fuel should be made available from the high-grade coking and steaming coals of the Bering River and Matanuska fields or from the Cook Inlet lignites. (See pp. 48–49.) It has been shown that some siliceous ores could be obtained locally and that limestone is not far distant.

The climate of Prince William Sound is no deterrent to operations throughout the year. Many of the ore bodies are topographically so located that they could be undercut. Timber, though not abundant, is ample for the purposes of mining. Small water powers are fairly abundant, and there are also some larger ones.[15] During the era of high prices there has been a shortage of labor in all Alaska mining camps. As a consequence miners' wages on the Sound have of late been about 10 per cent higher than in the lode-mining districts of the States. Should copper mining ever develop on a large scale, there is no reason to believe that this difference would continue. On the whole, the controlling physical conditions on Prince William Sound are favorable to fairly low operating costs, though probably higher than in southeastern Alaska.

COPPER RIVER REGION.

The richest copper lodes of Alaska are those developed by the Kennecott group of mines and are tributary to the Copper River & Northwestern Railroad. (See Pl. II, in pocket.) These deposits are near the east end of a copper-bearing belt, which has been traced some 50 miles westward along the southern foothills of the Wrangell Mountains and as measured by present discoveries is from 5 to 15 miles in width. The belt takes its name, the Kotsina-Chitina district, from the two principal rivers which carry its drainage into Copper River. There is evidence that this zone of mineralization extends eastward into the upper Chitina basin. Some cupriferous lodes have also been found southwest of the main belt, near the valley of Copper River. All these deposits may be regarded as a part of the same copper-bearing province, which finds outlet to tidewater over the railroad terminating at Cordova.

The enormous copper production of the Kennecott mines has focused public attention on the types of lodes which have yielded these rich ores almost to the exclusion of all other types. There are, however, within the district a number of other forms of copper occurrence that are not without promise, though as yet unproductive. To arrive at some measure of the potential value of the district as a future source of copper it will be desirable to sketch the

[15] Ellsworth, C. E., and Davenport, R. W., A water-power reconnaissance in south-central Alaska: U. S. Geol. Survey Water-Supply Paper 372, pp. 72-110, 1915.

salient geologic features of several types of copper lodes which it includes. It will not be necessary to present details, for these are contained in many publications, notably in the reports of F. H. Moffit, who has devoted many years to a study of the Copper River region. Most of the facts here to be presented will be taken from Moffit's reports. The following list of publications relating to the district includes those of most importance to the present discussion. They are all Geological Survey publications except the last.

Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: Bull. 374, 1909.

Moffit, F. H., Mining in the Kotsina-Chitina district: Bull. 379, pp. 153–160, 1909.

Moffit, F. H., Mining in the Chitina district: Bull. 442, pp. 158–163, 1910.

Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: Bull. 448, 1911.

Moffit, F. H., The Chitina district: Bull. 520, pp. 105–107, 1912.

Moffit, F. H., Mining in Chitina Valley: Bull. 542, pp. 81–85, 1913.

Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: Bull. 576, 1914.

Moffit, F. H., Mineral deposits of the Kotsina-Kuskulana district: Bull. 622, pp. 103–117, 1915.

Moffit, F. H., Mining in the lower Copper River basin: Bull. 662, pp. 155–182, 1917.

Moffit, F. H., The upper Chitina Valley, Alaska: Bull. 675, 1918.

Moffit, F. H., and Mertie, J. B., The Kotsina-Kuskulana district, Alaska: Bull. — (in preparation).

Bateman, A. M., and McLaughlin, D. H., Geology and ore deposits of Kennecott, Alaska: Econ. Geology, vol. 15, pp. 1–80, 1920.

The copper lodes here to be considered are of five more or less distinct types and geologic association—(1) replacement deposits in limestones, (2) veins and disseminated deposits in greenstones, (3) contact deposits between limestone and intrusive diorite, (4) disseminated deposits in fractured diorite, and (5) fissure veins in various types of rock, in many of which copper occurs only as an accessory mineral.

The dominating feature in the economic geology of the district is the contact between the heavy Chitina limestone and a great series of the underlying ancient lavas called the Nikolai greenstone. Along the general zone of this contact, which is a very conspicuous feature in the landscape, occur the most valuable ore bodies yet found in the district. A little copper mineralization has occurred at many places along the actual line of demarcation, but the copper has not proved to be concentrated enough to form ore bodies. All the ore bodies as yet productive lie in the limestone above the contact, but the greenstones below also contain copper deposits, and some copper-bearing lodes cross the contact.

Up to the present time interest has largely centered on ore bodies lying entirely above the contact and within the limestone, for it is here that the very rich bonanza deposits occur, the source of all the copper as yet produced. These deposits are due to the replace-

ment of limestone by copper sulphides along fractures produced by faulting. They consist mostly of chalcocite, with locally some covellite, bornite, enargite, and chalcopyrite. These deposits have several forms—well-defined veins, stockworks made up of sulphide-bearing veinlets in shattered limestone, and masses, some of which are very large, of solid sulphides having irregular outline. It is the last type that has yielded the very rich copper ores for which the district is so famous. Most of these replacement deposits include all the above-described phases. The massive sulphides as mined contain but little gangue, and this is chiefly lime. The stockwork deposits are of lower grade, and in these much calcite gangue is mixed with the ore. Ores of this class produced at the Kennecott mines are concentrated by oil flotation before shipment. The ores of the replacement veins in the limestone of some localities are made up of chalcocite and bornite in varying proportions and also carry but little gangue. The Kennecott ores carry no gold but an appreciable amount of silver. In 1919 the average copper content of the shipping ore from the Kennecott mines was 45.51 per cent and of the concentrating ore 10.24 per cent.[15a]

The limestone-greenstone contact, with which copper deposits of the type above described are associated, has been traced in the district for a linear distance of more than 60 miles. Sufficient evidence of mineralization in the limestone has been found in at least a score of localities to lead to the staking of claims, and on some of them considerable development work has been done. As yet, however, no large ore bodies have been proved except those of the Kennecott mines. This is perhaps not an encouraging result of 20 years of prospecting. It should be noted, however, that, as will be shown, copper-bearing minerals are much more widely distributed in the greenstone than in the limestone, and that much of the prospecting has been in the former.

The rather complete geologic information available about the district is interpreted by the writer as indicating that there is no reason why other workable deposits of the Kennecott type should not be uncovered. There are no special geologic conditions at the developed mines which are not found at other places.

One fact regarding the outcrops of such ore bodies should be noted. The outcrop that led to the discovery of the Bonanza lode, the first of the Kennecott group to be opened, was a very large one. Here by chance of erosion the outcrop was on one of the enormous ore shoots and stood up as a great mass of copper carbonate on a sharp crest. Had only one of the leaner parts of the lode appeared at the surface it would have been very inconspicuous and might not have received much attention. As it was, very little development work

[15a] Kennecott Copper Corp. Fifth Ann. Rept., 1919, p. 5, New York, 1920.

on the Bonanza lode revealed a sufficient tonnage to justify the construction of nearly 200 miles of railroad.

In contrast to the conditions above set forth are those which brought about the development of the Jumbo lode. The outcrop of this lode consisted of a zone of fracturing along which fine seams of chalcocite occurred. Though it was a very promising place for prospecting, there was nothing on the surface to justify a belief that an enormous ore body lay underneath, as proved to be the case. Had the development of the district depended on the surface showings of the Jumbo instead of those of the Bonanza, it would doubtless have been long delayed.

It is therefore reasonable to suppose that there may be other large ore bodies in the limestone at localities where there is little evidence of their presence on the surface, but these statements are not presented as an argument for haphazard underground exploration of the limestone for ore bodies that do not crop out. Such work is justified only at localities that show surface evidence of faulting and fracturing, as well as of some copper mineralization. The facts presented justify the belief that other workable deposits of the Kennecott type will be found.

Traces of copper are present in much of the unaltered greenstone in the district, and local mineralization of the ancient lava flows is also common. Bateman and McLaughlin [16] state that the examination of many greenstone localities shows "that hardly a greenstone specimen could be found which did not show appreciable copper, and numerous assays of greenstones from unmineralized areas yielded 0.11 to 0.60 per cent copper." Such occurrences are of course of no present commercial importance, but copper in more concentrated form occurs in many localities in the greenstone. Mineralization in the greenstone has produced both well-defined fissure veins and usually less well-defined and more disseminated deposits, which in general follow zones of fracturing and shearing. These deposits are in part cavity fillings and in part replace the country rock. With them may also be classed the ill-defined deposits of sulphides and native copper occurring along joint planes and as amygdaloidal fillings of lavas.

The cupriferous veins that cut the greenstone and in part cross the contact into the limestone have furnished the best-defined ore bodies of the greenstone. Of such a type is the Nikolai lode, in the eastern part of the field, the first copper deposit found in the district. Veins of this type are essentially sulphide deposits containing one or more of the minerals bornite, chalcopyrite, chalcocite, and pyrite, with very rarely tetrahedrite. The gangue minerals are quartz and calcite with some epidote, but some veins consist almost entirely of sul-

[16] Op. cit., p. 19.

phides. Many deposits of this type have been found and some have been opened, but as yet none have shown any large tonnage of ore by the underground work done. The best hope for veins of this type lies in those that carry a high content of copper, and such veins, if accessible to the railroad, might be profitably exploited.

The larger deposits of the disseminated type in the greenstone have the same mineral character as the veins but are found in zones of shearing rather than in fissures. They carry bornite, chalcopyrite, chalcocite, and some native copper. Many of those developed are narrow groups of fissures which do not include any considerable mass of bedrock. In others the shear zones are much wider, and such deposits give promise of being commercial ore bodies. Within the shear zones there may be one or more veins forming ore shoots, or the deposit may consist only of mineralized fractured rock. Though no mines have been developed on deposits of this type, the indications are sufficiently encouraging to justify the belief that some of them may prove to be commercial ore bodies. It will be impracticable to list here the very many copper deposits of this type that have been more or less prospected in the district.

Many of these deposits carry more or less native copper in slabs and slugs and as amygdaloidal fillings. The evidence thus far obtained indicates that this native copper is all secondary and has resulted from the oxidation of sulphides. Therefore the native copper will probably not be found to any considerable depth. It should be noted, however, that the evidence of the alluvial deposits indicates that some very large masses of native copper occur in the greenstone. On Nugget Creek, near the west end of the district, a mass of native copper, estimated to weigh two or three tons, has been found, and smaller nuggets are very common. Thousands of pounds of native copper have been won from the Nizina placers, in the eastern part of the district, incidentally to the mining of gold.

Some copper deposits of contact-metamorphic origin have been found in the Kuskulana River basin, in the western part of the district.[17] These lie in the contact zone between limestone and intrusive diorite, and they are made up of irregularly distributed masses and veins of magnetite carrying pyrite and chalcopyrite. These contact deposits are essentially low-grade concentrating ores with some richer shoots of sulphide ores. Their mode of occurrence, so far as determined, is similar to that of the contact deposits of the Ketchikan district. (See pp. 15–16.)

Another type of copper lode has been found on Clear Creek, in the Kuskulana River basin.[18] At this locality a dioritic rock is intruded

[17] Moffit, F. H., Mining in lower Copper River basin: U. S. Geol. Survey Bull. 662, p. 160, 1917.

[18] Moffit, F. H., Mineral deposits of the Kotsina-Kuskulana district: U. S. Geol. Survey Bull. 622, p. 113, 1915.

into the greenstone. The diorite and adjacent parts of the greenstone have been fractured along a shear zone and are more or less mineralized by pyrite and chalcopyrite. These sulphides are distributed in small gash veins and in larger veins along the planes of movement. In general this is a low-grade disseminated deposit with some richer ore shoots. A deposit of somewhat similar character occurs in the Taral region.[19] Here there is a shear zone in greenstone near an intrusive diorite contact. The ore consists of a series of parallel veins of pyrite and chalcopyrite, which lie in the zone of shearing.

Fissure veins, valuable chiefly for their gold and silver content, have been found at several localities in the district, and some of them carry more or less chalcopyrite. Such a vein has been opened at the Midas gold mine, where it cuts dioritic rocks. No large ore bodies of this type have yet been revealed, and it remains to be determined whether any such deposits could be counted upon as possible sources of siliceous ore.

The Kotsina-Chitina copper district is easily accessible by the Copper River & Northwestern Railroad, which extends inland for 192 miles from Cordova, a good harbor and ice-free port on Prince William Sound. Outgoing shipments are on a down grade, and if a large tonnage were available reasonable freight rates should be expected. This railroad passes within 38 miles of the Bering River coal field (see pp. 47–48), and a short distance beyond this is the Katalla oil field (see pp. 52). These geographic facts would seem to favor the use of the copper deposits here described for the upbuilding of a local industry. The high-grade ores, with calcareous gangue, would meet ores of lower grade from Prince William Sound at Cordova, while near by there are sources of excellent fuel.

There is no great amount of timber in the Kotsina-Chitina district, but it is sufficient to meet the immediate needs of a mining industry. The district is one of strong relief, and most of the ore bodies now known could be developed by adits. There are some large water powers in this general region, but most of them are not near the ore bodies. There are no climatic conditions in the district which prevent mining throughout the year, though some difficulties are caused by snowslides.

Although the conditions above described are in general favorable to the developments of the copper deposits, the present situation presents many drawbacks. The railroad traverses the southern margin of the copper belt, making the district accessible as a whole, but many of the prospects are 5 to 25 miles from the track. No spurs have been built, and there are few wagon roads. This condition makes development work expensive. In the event of the opening

[19] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 51–52, 1914.

up of large ore bodies this situation would of course be met by providing connection with the railroad by spurs or aerial trams.

The present freight rates on the railroad are high. The rates on ore and concentrates from this district to the Tacoma smelter in 1920 ranged from $11.20 a ton on ore worth $25 a ton to $40.90 on ore worth $500. The railroad company contends that as it is not making expenses it can not afford to lower the rates.[19a] On the other hand, prospective operators hold that under the present rates no mining is possible except that of very high grade ore. Consequently but little development work is now under way. It would appear to be the part of wisdom to lower the rates with a view of encouraging a development that would produce enough ore to make the railroad a profitable venture in the future. As it is, no ore is shipped except the high-grade product of the Kennecott Mines Co., which controls the railroad. It should also be noted that there has not yet been a sufficient assured quantity of coal disclosed in the Bering River field to justify the extension of a branch line into the coal field, also that the Katalla oil field is as yet only a small producer. Aside from the question of freight rates, mining costs in the interior will certainly for a long time to come be higher than on the coast.

In view of these conditions an ore body of a given size and copper content which might if located on the coast be valuable if in the interior would at present be worthless. Nevertheless the situation of the Kotsina-Chitina copper deposits with reference to sources of fuel and to the ores of a different character on the Sound presents possibilities which should not be underestimated.

Productive mining in the Kotsina-Chitina district began in 1911. Up to the end of 1919 about 1,360,000 tons of copper ore had been mined, from which about 417,700,000 pounds of copper had been recovered. In 1919 the district produced 195,631 tons of ore, carrying 36,291,390 pounds of copper and 408,726 ounces of silver. (See p. 68.) No gold has been recovered from the copper of this district.

SUSITNA VALLEY REGION.

Evidences of copper mineralization have long been known at many widely separated localities in the basin of Susitna River, which flows into the head of Cook Inlet. Until the project of opening this province by a Government railroad was definitely entered upon in 1915 these deposits received but little attention. During the last five years there has been a good deal of prospecting for copper in this field, but as yet the amount of underground work is small and nowhere has any considerable quantity of ore been blocked out. Many of the prospects are far from the completed part of the railroad, and the cost of developing some of them has been prohibitive. As the railroad is pushed forward conditions improve, and the situation is also being helped by the construction of wagon roads and

[19a] The Copper River & Northwestern Railroad reported an operating loss for the year 1919 of $177,895.78 (Kennecott Copper Corp. Fifth Ann. Rept., 1919, p. 14, New York, 1920).

trails. Information about the geology and mineral resources of this region is to be found in the following Geological Survey publications:

Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: Bull. 500, 1912.

Capps, S. R., The Yentna district, Alaska: Bull. 534, 1913.

Martin, G. C., and Mertie, J. B., Mineral resources of the upper Matanuska and Nelchina valleys: Bull. 592, pp. 273–300, 1912.

Capps, S. R., The Willow Creek district, Alaska: Bull. 607, 1915.

Moffit, F. H., The Broad-Pass region, Alaska: Bull. 608, 1915.

Capps, S. R., The Turnagain-Knik region: Bull. 642, pp. 147–194, 1916.

Chapin, Theodore, The Nelchina-Susitna region, Alaska: Bull. 668, 1918.

Capps, S. R., Mineral resources of the upper Chulitna region: Bull. 692, pp. 177-186, 1919.

Capps, S. R., Mineral resources of the western Talkeetna Mountains: Bull. 692, pp. 187–205, 1919.

Chapin, Theodore, Mining developments in the Matanuska coal field: Bull. 712, pp. 131–167, 1920.

Chapin, Theodore, Lode developments in the Willow Creek district: Bull. 712, pp. 169–176, 1920.

The best known of the copper deposits of this region were formed by replacement along shear zones that traverse mainly limestone and ancient volcanic rocks. A number of prospects have been found in the western part of the Talkeetna Mountains, notably in the drainage basins of Talkeetna and Kashwitna rivers. The geology of this area is relatively simple; a series of andesitic lavas, with which some limestone is associated, are intruded by great stocks of granitic and dioritic rocks which form the main mass of the mountains. It appears that the copper mineralization is genetically related to the intrusion, as is the auriferous lode of the Willow Creek district, lying along the southern margin of the same intrusive mass. This inference is supported by the fact that some chalcopyrite-bearing auriferous lodes have been found in the Willow Creek district.

The copper-bearing lodes of the Talkeetna region occur as replacement deposits along shear zones cutting the greenstones. Their metallic minerals include chalcopyrite, pyrite, bornite, and arsenopyrite, and assays show that they carry gold and silver. The gangue is mostly quartz and some calcite.

There has been but little underground work in this region, but the surface exposures indicate that these deposits are essentially of a disseminated type, though they include some rich shoots of sulphide ores, chiefly chalcopyrite. There are in this region extensive areas in which the geologic conditions above described prevail; hence there is good reason to believe that other copper deposits may be found.

Evidence of some copper mineralization has also been reported to occur on the west side of the Susitna Valley, but these occurrences are not verified at this writing. In this region granitic and dioritic rocks invade sedimentary rock. Gold placers in this part of the province are direct evidence of mineralization.

In the upper Chulitna Valley, sometimes called the Broad Pass district, considerable work has been done on some ore bodies of rather complex composition. These are disseminated replacement deposits along fracture zones, and have been found chiefly in a limestone country rock but also in tuffs and cherts. The walls of these deposits are not everywhere well defined, and the ore bodies are rather irregular. They contain arsenopyrite, pyrite, sphalerite, chalcopyrite, pyrrhotite, stibnite, and galena, and assays show the presence of gold. The gangue is country rock and includes much calcite and some quartz. So far as yet determined these occurrences are of a disseminated type and of rather low grade. They include, however, some rich ore shoots.

It is evident from the above summary that as yet there is no assurance that valuable copper-bearing lodes occur in the Susitna region. It is fair to infer, however, from the geologic information at hand that the region is not to be ignored as a possible source of copper.

The close proximity of the high-grade coals of the Matanuska field (see pp. 47–48) favors the development of copper. The railroad will give an outlet to the coast at Anchorage certainly for at least half the year and to a good harbor at Seward throughout the year. (See Pl. II, in pocket.) After the railroad is completed there will still be need of spurs and branches to reach the known deposits of copper.

The timber of the province is not of a high grade but will meet the immediate needs of the mining industry. There are no climatic obstacles to operations throughout the year. Little is known about the water-power resources, but no doubt some are available. On account of distance to the railroad, isolation, and scarcity of labor, the cost of preliminary developments will be high. Should a large mining industry be developed and a permanent population be attracted thereby, the cost of labor will be less. It is certain, however, that mining costs will always be greater in the Susitna basin than on the coast.

ILIAMNA REGION.

Iliamna Bay, on the west side of Cook Inlet, is a fair harbor and usually open to navigation at all times, though in winter difficulties with float ice are occasionally encountered.[20] Work has been done on some copper prospects about 10 miles inland from Iliamna Bay,[21] on contact deposits occurring in the zone of metamorphism between limestones and dioritic intrusives. The metallic contents of the ores are chalcopyrite, pyrite, and magnetite, and the gangue

[20] The conditions affecting transportation in this region are presented in Railway routes in Alaska: Alaska Railroad Comm. Rept., 62d Cong., 3d sess.. H. Doc. 1346, pp. 90–91, 105–106, 1913.

[21] Martin, G. C., and Katz, F. J., A reconnaissance of the Iliamna region: U. S. Geol. Survey Bull. 485, pp. 113–126, 1912.

consists of lime silicates, calcite, and some quartz. Information at hand indicates that the ores are chiefly calcareous. These occurrences are of the same general character as the contact deposits of the Ketchikan district (p. 15), but as yet no large ore bodies have been opened. The same region contains some auriferous quartz veins. Another occurrence of copper is reported about 30 miles southwest of those above described, near Kamishak Bay,[22] apparently in a contact zone between volcanic and intrusive rocks. The copper occurs as chalcopyrite, and the ore is said to be of low grade. There are some large water powers in this general province, and some local timber. Present knowledge does not warrant any predictions as to the value of the copper deposits of the Iliamna region.

NABESNA-WHITE RIVER REGION.

The occurrence of copper has long been known in the headwater regions of White River, a tributary to the Yukon, and on Nabesna River, a tributary to the Tanana. This province can now be reached from the established routes of transportation only by long overland journeys. Its development as a copper province will be possible only by large expenditures for railroad construction.[23]

The copper occurs in formations which stretch from the international boundary westward along the northern base of the Wrangell Mountains to Nabesna River, a distance of some 200 miles. Evidence of mineralization has been found at several places along this entire belt, but most of the important prospects are near its two ends.[24]

In the Nabesna region deposits of bornite and chalcopyrite, associated with garnet, calcite, epidote, hematite, and a little molybdenite, have been found. These minerals occur in irregular ore bodies that lie in the contact zone of limestone and diorite and carry some gold. In the basin of Chisana River, a tributary to the Tanana, some small chalcopyrite-bearing quartz veins cut ancient lava flows. In the White River basin native copper has been found as a primary mineral in the cavities of ancient amygdaloidal, basaltic lavas. This is the only region in Alaska in which primary native copper has been found. It should be noted that native copper which is clearly secondary also occurs in this region as slabs and nuggets in ancient lavas. These are of the same general type as those in the Chitina-Kuskulana district described above.

This belt contains some promising ore bodies, and evidence of copper mineralization is widely distributed. Its deposit of native

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[22] Brooks, A. H., The Alaska mining industry in 1913: U. S. Geol. Survey Bull. 592, p. 64, 1914.

[23] A description of the various possible railroad routes into this region is contained in the report of the Alaska Railroad Commission (62d Cong., 3d sess.), H. Doc. 1346, pp. 44-53, 67-69, 70-71, 1913.

[24] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, 1916. Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, 1916.

copper especially gives promise of being valuable. Were the region not so inaccessible it would long ago have been thoroughly prospected. As it is, the developments have been confined to only a few claims.

MISCELLANEOUS LOCALITIES.

The districts above described are those that give the most promise of having important potential copper resources. There are also scattered occurrences of copper mineralization which for the sake of completeness will here be briefly recorded.

Some copper-bearing deposits have been found on the Alaska Peninsula, near Prospect and Balboa bays.[25] These deposits occur along shear zones in volcanic rocks and carry pyrite, galena, sphalerite, chalcopyrite, and quartz. There is no evidence at hand that any commercial ore bodies have been found. It has long been reported that copper has been found on some of the Aleutian Islands, but nothing is known of its form of occurrence or of the locality of the alleged discovery. A little auriferous mineralization has occurred on Unalaska Island along the margin of an intrusive granite. It is worthy of note that native copper was long ago found on Midni Island, of the Commander group, off the east coast of Siberia. These islands lie in an extension of the axis of the Aleutian chain and presumably belong to the same geologic province.

A little copper mineralization is reported by prospectors in the Alaska Range near the head of McLaren River, and they have brought back specimens of chalcocite. This fact would hardly be worthy of note except that the occurrence is reported to be in limestone near a greenstone contact, a position which suggests a similarity to some of the deposits of the Chitina-Kuskulana district. What is known of the geology of this region[26] confirms the description furnished by the prospectors who made the discovery. A little copper has also been found in association with greenstones and diorites in the Paxon region, traversed by the Valdez-Fairbanks wagon road. This general province is therefore a possible field for copper lodes.

A copper-bearing quartz lode has been prospected in the Russian Mountains, 12 miles from Kolmakoff, on Kuskokwim River.[27] It is composed chiefly of chalcopyrite and arsenopyrite and contains gold and silver. The newly discovered gold-bearing lodes of the Nixon Fork district, in the upper Kuskokwim Valley, carry a little copper.

Copper-bearing deposits have been found on Seward Peninsula, and some of these have been developed in a small way, and a few

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[25] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 129, 131, 1911.

[26] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, 1912.

[27] Maddren, A. G., Gold placers of the lower Kuskokwim: U. S. Geol. Survey Bull. 622, pp. 304-305, 1915.

test shipments of ore have been made. The best known of these deposits occur as impregnated zones along or near limestone-schist contacts. The ore minerals are chalcopyrite and bornite, with considerable copper carbonate near the surface.[29]

Copper-bearing lodes have been found in several places in the Noatak-Kobuk region of northern Alaska.[30] Considerable prospecting has been done on some of these lodes near Shungnak, in the middle Kobuk Valley. (See map, Pl. II, in pocket.) These lodes occur in limestone along zones of brecciation. They carry bornite, chalcopyrite, galena, and pyrite, and assays show the presence of gold and silver. Were these deposits not so isolated they would undoubtedly have attracted more attention.

In 1919 11 copper mines were operated in Alaska, producing 492,644 tons of ore, from which 47,220,771 pounds of copper was recovered. (See p. 68.) Of this total 451,445 tons of ore was concentrated by flotation at the mines, yielding 52,944 tons of concentrates. Nearly all this ore was treated at the Tacoma smelter. One small mine in the Ketchikan district shipped its ore to the Anyox smelter, in British Columbia.

The reserve tonnage of the present Alaskan copper developments is small. On the other hand, the evidence of strong copper mineralization in several of the accessible mining districts of Alaska and the widespread distribution of copper ores give every assurance for the future. It can therefore be confidently predicted that Alaska's copper industry will grow when transportation is improved and general industrial conditions are revived.

SILVER AND LEAD.

Alaska has produced about 9,000,000 ounces of silver and 4,184 tons of lead, practically all won incidentally to the mining of other metals. The silver has come from the gold placers and the gold and copper lodes. Its annual output has therefore fluctuated with the production of gold and copper. With an increased output of these metals more silver will be produced. Most of the lead has been obtained from the gold mines of the Juneau district.

Silver-lead ores in the form of galena have a wide distribution in Alaska. Such ores are found in the Ketchikan district, in Seward Peninsula, in the Koyukuk region, in the Fairbanks district, in the Mentasta Pass region (upper Tanana), and in the Kantishna, Ruby, and other districts. Little attention was paid to these ores until the recent great advance in the price of silver. Since then galena de-

[29] Mertie, J. B., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, pp. 440–441, 1918. Smith, P. S., Investigations of mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, pp. 241–244, 1908.

[30] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 147–151, 1913.

posits have been sought for and prospected, especially those that carry a high percentage of silver. The most promising recent discovery is a lode in the Kantishna district. The evidence in hand does not indicate that any considerable bodies of galena ore have been found. With the improvement in mining conditions such ores will be developed, but there is as yet nothing to indicate that they form an important part of the potential mineral reserves of Alaska.

TIN.[31]

Alaska has produced about 972 tons of metallic tin, which has nearly all come from the placers of the York district at the west end of Seward Peninsula. Tin deposits, both placers and lodes, were discovered by the United States Geological Survey in 1900 and 1902. Developments began in a small way on placer tin in 1902 and the first dredge was installed in 1911. Since then two or three dredges have been employed in tin mining. A number of discoveries of lode tin have been made in the York district. Practically no tin has been produced from lodes, but lode developments have been underway since 1903. The only considerable underground exploration has been at the Lost River mine, where a mill is now under construction.

Some placer tin has also been produced incidentally to gold mining in the Hot Springs district of the Tanana Valley and in smaller amounts in other Yukon districts. Placer tin has also been found in the gravels of Yentna River, which is tributary to the Susitna.

Though there has been some systematic search for tin in Alaska during the last two decades, promising deposits have been found only in the York and Hot Springs districts. No new deposits of placer tin have been discovered in the York district in recent years, and there is no certainty that this form of tin mining will be continued there when the deposits now being exploited are worked out. No tin placers which, under present economic conditions, will warrant exploitation for their tin alone have yet been found in the Yukon districts. When costs of operation are reduced placer-tin mining may be developed in the Hot Springs and other districts. The distribution of the alluvial tin in this district also justifies the hope that tin-bearing lodes may yet be discovered. Meanwhile, the best hope of the continuation of Alaska tin mining is based on the lode tin of the York district. The Lost River mine, in this district,

[31] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, 1908.

Eakin, H. M., A geologic reconnaissance of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 37–38, 1913; Tin mining in Alaska: U. S. Geol. Survey Bull. 622, pp. 81–94, 1915.

Chapin, Theodore, Tin deposits of the Ruby district: U. S. Geol. Survey Bull. 692, p. 337, 1919.

Harrington, G. L., Tin mining in Seward Peninsula: U. S. Geol. Survey Bull. 692, pp. 353–361, 1919.

Steidtmann, Edward, and Cathcart, S. H., The York tin deposits: U. S Geol. Survey Bull — (in preparation).

is the only property sufficiently developed to justify the belief that it will soon become a producer, yet there are other deposits in the region which deserve prospecting.

The above-stated facts do not show any large potential tin reserves in Alaska, but the rather wide distribution of the tin deposits gives hope of future discoveries. There is no evidence that the tin output will decrease in the near future, yet a large increase in production must depend on the development of deposits not yet discovered.

PLATINUM.

Small quantities of platinum and allied metals have been found at widely separated localities in Alaska. The only considerable deposit of these metals thus far developed is in the Ketchikan district, where the ores of the Salt Chuck copper mine (see p. 18) carry a sufficient percentage of palladium to be worked for that metal alone.

Small quantities of platinum have been recovered incidentally to gold placer mining in several districts.

Localities where placer platinum and minerals of allied groups have been found.

District.	Creek.	Notes.
Yentna (Susitna Basin) [a]	Cache Creek	Minute quantities.
	Poorman Creek	Do.
	Wilson Creek	Do.
	Long Creek	Do.
	Kahiltna River	Do.
Kodiak Island [b]	Canvas Point	Do.
Chistochina (Slate Creek) [c]	Slate Creek	Small quantities recovered.
	Miller gulch	Do.
Innoko district (Tolstoi) [d]	Boob Creek	Do.
Koyuk (southeastern part of Seward Peninsula). [e]	Dime Creek	Do.
Fairhaven (northeastern part of Seward Peninsula). [e]	Bear Creek	Do.
	Sweepstake Creek	Do.
Lower Kuskokwim [f]	Aloric River	Minute quantities.
Marshall [f]	Lower Yukon River	Do.

[a] Mertie, J. B., Platinum-bearing gold placers of Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 233-263, 1917.
[b] Maddren, A. G., The beach placers of the west coast of Kodiak Island: Idem, p. 316.
[c] Chapin, Theodore, Platinum-bearing auriferous gravels of Chistochina River: Idem, pp. 137-141.
[d] Harrington, G. L., The gold and platinum placers of the Tolstoi district: Idem, pp. 339-351.
[e] Harrington, G. L., The gold and platinum placers of the Kiwalik-Koyuk region: Idem, pp. 369-400.
[f] Martin G. C., Mineral resources of Alaska, 1917: U. S. Geol. Survey Bull. 692, p. 7, 1919.

The total output of platinum, palladium, and other metals of the platinum group is about 915 ounces. Except at the Salt Chuck mine the recovery of these rare metals was only incidental to mining of placer gold. The record does not indicate that Alaska will become an important source of platinum minerals unless new discoveries are made.

ANTIMONY.

Antimony ore, in the form of stibnite, is one of the most widely distributed minerals in Alaska,[32] but most of the larger desposits are in the interior. The high price and ready market for antimony during the war led to the development of stibnite ores at several localities, especially in the Fairbanks and Nome districts. This temporary demand subsided at the end of the war and antimony mining ceased. A total of 2,492 tons of stibnite was produced between 1916 and 1918.

The facts in hand indicate that there are large reserves of antimony ore in Alaska and that they are mostly in the less accessible parts of the Territory. Their future development is dependent on market and on cost of transportation.

TUNGSTEN.

Tungsten-bearing lodes were developed at Fairbanks and Nome when the war needs led to an abnormal demand for this metal. Considerable tungsten ore[33] was shipped from these properties between 1916 and 1918, and some scheelite was also recovered from the concentrates of gold dredges at Nome and Iditarod. With the break in the tungsten market after the war all these operations ceased. In all about 86½ tons of Alaska scheelite concentrates have been mined and marketed.

Wolframite and scheelite occur in some of the tin ores of the York district, Seward Peninsula, but these deposits have been only slightly developed. Wolframite has also been found in association with some of the gold placers of the Yukon-Tanana region. In 1916 a little wolframite, won from the placers, was shipped from the Birch Creek district. A scheelite-bearing vein has been found on Baranof Island near Sitka.

These facts indicate that tungsten ores are rather widely distributed in Alaska. Should a market arise for this ore on the west coast, some of the deposits would no doubt be developed.

QUICKSILVER.

Quicksilver deposits, in the form of cinnabar-bearing veins, have long been known on Kuskokwim River.[34] Cinnabar is also not an uncommon accessory mineral of some of the gold placers, notably on Daniels Creek, in the Bluff region of Seward Peninsula, on some of the creeks of the Iditarod district, and on Candle Creek, in the Kuskokwim basin near McGrath. The only developed quicksilver mine in Alaska is the Parks property, on the north bank of the Kusko-

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[32] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, 1916.

[33] Mertie, J. B., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 418-424, 1917, Lode mining and prospecting on Seward Peninsula: Idem, pp. 436-437.

[34] Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: U. S. Geol. Survey Bull. 622, pp. 274-280, 1915.

kwim, about 330 miles from its mouth. Here some cinnabar ore has been retorted, and the quicksilver thus produced was sold to the placer miners of Alaska. There has been some prospecting of other quicksilver deposits in this general region, but none of the properties have been sufficiently developed to give assurance of a definite output.

There is reason to believe that the lower Kuskokwim will continue to be a producer of quicksilver, but no facts are at hand which indicate that quicksilver mining will become a large industry in Alaska.

CHROMITE.

Considerable bodies of chromite ore have been found at the southwest end of Kenai Peninsula,[35] and during the war the large demand for chromite led to the productive development of one of them, which lies directly on tidewater. The large tonnage of ore in sight and the accessibility of the deposit make it certain that this deposit will be mined when a market can be found for the product. What seems to be a large deposit of chromite has also been found at Red Mountain, which is about 7 miles from the one above described. Some chromite has been found in other parts of Alaska, but as yet no other commercial ore bodies are known.

NICKEL.

A nickel-bearing copper deposit has been developed in a small way on the west side of Chichagof Island, about 70 miles north of Sitka. Some nickel has been found in other deposits of similar geologic character in this general region.[36] These deposits are found in association with norite or diorite, which has a rather wide distribution in the district. Their geologic association is the same as that of the nickel ores of Sudbury, Canada. There is a possibility that commercially valuable nickel ores may be developed in this district.

Another nickel-bearing copper lode occurs on Canyon Creek, in the lower Copper River valley.[37] Traces of nickel have been found in gold ores sent to the Geological Survey from the McGrath district, in the Kuskokwim Valley. Some of the copper ores of the Ketchikan district contain traces of nickel (p. 15), and it is reported that the same is true of some of the copper ores of the Prince William Sound region. It will be evident from the above statements that information about the nickel deposits of Alaska is not complete enough to justify an estimate of their future value.

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[35] Gill, A. C., Preliminary report on the chromite of Kenai Peninsula: U. S. Geol. Survey Bull. 712, pp. 99–129, 1919; Chromite of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[36] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 125–133, 1919.

[37] Overbeck, R. M., Nickel deposits in the lower Copper River valley: U. S. Geol. Survey Bull. 712, pp. 91–98, 1919.

MOLYBDENITE.

Molybdenite is not an uncommon accessory mineral in some of the Alaska gold and copper ores and has also been found at several localities in more concentrated form. The best-developed Alaska molybdenite lode is near Shakan, on Prince of Wales Island.[38] A molybdenite lode has been found at Lemesier Island, in Icy Strait.[39] Some development work is reported on a molybdenite-bearing lode on the railroad near Skagway.[40] Molybdenite has also been found on Canyon Creek, a tributary to upper Chitina River and about 50 miles from McCarty,[41] and on Dry Delta River a tributary to the Tanana.[42] Except for that at Shakan, none of these deposits have been sufficiently developed to prove their commercial importance. There has been no molybdenite produced in Alaska.

BISMUTH.

A small bismuth-bearing vein has been found on Charley Creek, in the Nome district, but is undeveloped.[43] Bismuth has been found in gold prospects at two localities in the Tanana Valley—on Eva Creek,[44] a tributary to Totatlanika Creek, and on Melba Creek,[45] in the Fairbanks district—but little is known of the extent of these deposits. There has been no production of bismuth in Alaska.

IRON.

In the absence of any considerable iron industry on the Pacific coast there has been no incentive to search for iron ores in Alaska. The largest deposits known consist of magnetite associated with copper ores—the contact-mètamorphic deposits of the Ketchikan district (p. 15). J. B. Mertie, who has made a rough estimate of the quantity available from these deposits, places the minimum reserve at 10,000,000 tons, with possibly an average copper content of 0.5 per cent. This estimate is based on an appraisal of the probable depth of the known deposits and on the assumption that all the ore would be available for mining. There are no accurate data at hand on the mean iron content of these ores, nor is it known whether the phosphorus contents are everywhere below the Bessemer limit. Some analyses of the Mount Andrew magnetite ore made many years ago gave a phosphorus content of 0.02 per cent.[46] The

[38] Chapin, Theodore, Mining developments in the Ketchikan district: U. S. Geol. Survey Bull. 692, p. 89, 1919.

[39] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, p. 17, 1912.

[40] Brooks, A. H., The Alaska mining industry in 1916: U. S. Geol. Survey Bull. 662, p. 25, 1918.

[41] Brooks, A. H., The Alaska mining industry in 1915: U. S. Geol. Survey Bull. 642, p. 54, 1916.

[42] Martin, G. C., The Alaska mining industry in 1918: U. S. Geol. Survey Bull. 712, pp. 23–24, 1920.

[43] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, p. 133, 1913.

[44] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351–362, 1917.

[45] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 330–331, 1914.

[46] Brooks, A. H., The Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 102, 1902.

Kuskokwim, about ... miles from its mouth. Here some cinnabar ore has been stoped, and the quicksilver thus produced was sold to the placer miners of the region. There has been some prospecting of other cinnabar deposits in this general region, but none of the properties have been sufficiently developed to give assurance of a definite output.

There is reason to believe that the lower Kuskokwim will continue to be a producer of quicksilver, but no facts are at hand which indicate that quicksilver mining will become a large industry in Alaska.

CHROMITE.

Considerable bodies of chromite ore have been found at the southwest end of Kenai Peninsula[a] and during the war the large demand for chromite led to the productive development of one of them, which lies directly on tidewater. The large tonnage of ore in sight and the accessibility of the deposit make it certain that this deposit will be mined when a market can be found for the product. What seems to be a large deposit of chromite has also been found at Red Mountain, which is about 7 miles from the one above described. Some chromite has been found in other parts of Alaska, but as yet no other commercial ore bodies are known.

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A nickel-bearing copper deposit has been developed in a small way on the west side of Chichagof Island about 7 miles north of Sitka. Some nickel has been found in other deposits of similar geologic character in this general region.[b] These deposits are found in association with norite or diorite, which has a rather wide distribution in the district. Their geologic association is the same as that of the nickel ores of Sudbury, Canada. There is a possibility that commercially valuable nickel ores may be developed in this district.

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[a] Gill, A. C., Preliminary report on the chromite of Kenai Peninsula: U. S. Geol. Survey Bull. 712, pp. 99-129, 1920; Chromite of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[b] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 129-136, 1919.

[c] Overbeck, R. M., Nickel deposits in the lower Copper River valley: U. S. Geol. Survey Bull. 712, pp. 91-98, 1920.

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[44] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351-362, 1917.

[45] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 330-331, 1914.

[46] Brooks, A. H., The Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 102, 1902.

possibility that these ores contain titanium should also be considered. On account of the presence of sulphides the sulphur content of the ores will be high. Similar deposits have been mined on Tuxedo Island, in British Columbia, and these contain an average of 55 to 60 per cent of metallic iron,[47] and the phosphorus content of most of them is low enough to make them fall within the Bessemer limit, but the sulphur content is high.

Deposits of iron ore of the segregated type occur near Haines, in southeastern Alaska, and have been developed in a small way, but their commercial value remains to be established. According to Knopf,[48] they consist of primary magnetite disseminated in a basic rock composed of pyroxene and hornblende. The best specimens seen carried a maximum of 30 per cent of magnetite. A microscopic examination showed the presence of apatite, and the analysis of one sample showed 3.91 per cent of titanium oxide.

A deposit of magnetite ore has been discovered on the north shore of Tuxedni Bay (Snug Harbor), an indentation of the west shore of Cook Inlet. The deposit has been described by prospectors to be of considerable magnitude and to occur near the contact of a granitic intrusive in volcanic rocks. The ore body has been staked but is undeveloped.

Schrader[49] described a magnetite ore body which appears to be a vein in the Nabesna region. This vein is well defined and occurs at a contact between limestone and diabase. Grant and Higgins [50] report the occurrence of hematite and magnetite bearing veins in the Prince William Sound region. Some magnetite also occurs in the contact copper deposits of the Iliamna region (pp. 33–34).

A little work has been done on some iron deposits on Seward Peninsula about 25 miles northwest of Nome. As exposed the iron-ore bodies consist principally of limonite veins and stockworks and their residual products,[51] occurring in limestone. Other minerals found in the deposits are hematite, galena, pyrolusite, and small quantities of gold. An analysis of the samples from one deposit showed 54 per cent of iron, no titanium, and 0.13 per cent of P_2O_5. The surface evidences indicated that the mineralizing agents had affected considerable areas.

The above brief review indicates that Alaska contains a number of iron-ore deposits, of which the most promising are those of the

[47] Lindeman, Elmar, Iron-ore deposits of Vancouver and Texedo islands, British Columbia: Canada Dept. Mines, Mines Branch, No. 47, Ottawa, 1910.

[48] Knopf, Adolph, The occurrence of iron ore near Haines: U. S. Geol. Survey Bull. 442, pp. 144–146, 1910. Eakin, H. M., The Porcupine gold-placer district: U. S. Geol. Survey Bull. 699, pp. 27–29, 1919.

[49] Mendenhall, W. C., and Schrader, F. C., Mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, pp. 65–66, 1903.

[50] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, pp. 78–79, 1910.

[51] Eakin, H. M., Iron-ore deposits near Nome: U. S. Geol. Survey Bull. 622, pp. 361–365, 1915.

Ketchikan district. It would appear that the value of the Ketchikan deposits will depend on finding a commercial method of recovering the low copper contents, as well as utilizing the iron.

COAL.

GENERAL OCCURRENCE.

Formations that are known to be locally coal bearing are widely distributed in Alaska and occupy an aggregate area of more than 12,000 square miles. (See Pl. II, in pocket.) About 80 per cent of Alaska is unsurveyed, and some of the unexplored regions may contain coal. It is therefore not impossible that the total area of the coal-bearing formations may far exceed 12,000 square miles. Any additions that may be made to the known coal reserves as a result of future explorations will probably not greatly increase the immediately available stores of fuel, which alone are here under discussion. Most of the regions tributary to the existing lines of transportation or those under construction are sufficiently explored to indicate whether or not they contain coal. Outcrops of coal are not easily overlooked, either during hasty exploration or by the prospector, and, therefore, the coal-bearing areas already outlined in a rough way, though many have not been surveyed, probably include much the larger part of those that will be available for use in the immediate future. In any event, it is with reference to these known coal fields, and not to possible discoveries in unsurveyed tracts, that the future of the coal-mining industry must here be discussed. The Alaska reserves in general may be said to include enormous quantities of lignite, considerable low-grade bituminous coal, much smaller quantities of high-grade bituminous coal, and some anthracite. The bituminous coals are the highest-grade coals found on the west coast of the American continent and are comparable in composition to the best Appalachian fuels. It is on these high-grade coals that the present development of the coal-mining industry in Alaska depends, for they are the only fuels suitable for export.

PUBLICATIONS RELATING TO ALASKA COAL FIELDS.

Surveys and investigations of the Alaska coal fields were begun by the Geological Survey in 1902 and have been continued as funds were available up to the present time. Many geologists have taken part in this work, but nearly all the detailed surveys have been made by George C. Martin. The following is a list of the principal Survey and other official publications relating to Alaska coal. Some of these reports deal specifically with individual coal fields; in others the reference to coal is only incidental to the discussions of mineral resources.

U. S. GEOLOGICAL SURVEY.

GENERAL.[52]

Martin, G. C., Markets for Alaska coal: Bull. 284, pp. 18–29, 1906.

Brooks, A. H., Alaska coal and utilization: Bull. 442, pp. 47–100, 1911.

MATANUSKA COAL FIELD.

Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: Bull. 500, 1912.

Martin, G. C., and Mertie, J. B., Mineral resources of the upper Matanuska and Nelchina valleys: Bull. 592, pp. 273–300, 1914.

Martin, G. C., Geologic problems at the Matanuska coal mines: Bull. 692, pp. 269–282, 1919.

Chapin, Theodore, Mining developments in the Matanuska coal field: Bull. 712, pp. 131–167, 1920.

Chapin, Theodore, Mining develpoments in the Matanuska coal fields: Bull 714, pp. 197–199, 1921.

BERING RIVER COAL FIELD.

Martin, G. C., Geology and mineral resources of Controller Bay region, Alaska: Bull. 335, 1908. (This publication contains a detailed description of the Bering River coal field.)

SOUTHEASTERN ALASKA.

Wright, C. W., A reconnaissance of Admiralty Island: Bull. 287, pp. 151–154, 1906.

Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: Bull. 347, pp. 59–60, 1908. (Coal on Kupreanof Island.)

YAKUTAT AND YAKATAGA.

Tarr, R. S., and Butler. B. S., The Yakutat Bay region, Alaska: Prof. Paper 64, pp. 168–169, 1909.

Maddren, A. G., Mineral deposits of the Yakataga district: Bull. 592, pp. 147–148, 1914.

COOK INLET AND KENAI PENINSULA

Atwood, W. W., Mineral resources of southwestern Alaska: Bull. 379, pp. 116–121, 1908. (Tyonek coal field.)

Martin, G. C., Western part of Kenai Peninsula: Bull. 587, pp. 104–110, 1915. (Kachemak Bay coal field.)

SOUTHWESTERN ALASKA.

Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: Bull. 467, 1911. (Herendeen Bay, Chignik, and Unga coal fields.)

Martin, G. C., Mineral deposits of Kodiak and neighboring islands: Bull. 542, p. 136, 1913.

SUSITNA REGION.

Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper 70, p. 188, 1911.

Capps, S. R., The Yentna district, Alaska: Bull. 534, p. 72, 1913.

Capps, S. R., Mineral resources of the upper Chulitna Valley: Bull. 692, pp. 231–232, 1919.

Mertie, J. B., Platinum-bearing gold placers of Kahiltna Valley: Bull. 692, pp. 263–264, 1919. (Coal of Cache Creek.)

Moffit, F. H., The Broad Pass region, Alaska: Bull. 608, pp. 76–77, 1915.

NENANA COAL FIELD.

Capps, S. R., The Bonnifield region, Alaska: Bull. 501, 1912.

Martin, G. C., The Nenana coal field, Alaska: Bull. 664, 1919.

Capps, S. R., The Kantishna district, Alaska: Bull. 687, pp. 109–113, 1919.

[52] Information on progress of Alaska coal mining and of coal production and consumption are contained n *the annual reports* on the mineral resources of Alaska, published as Bulletins 259, 284, 314, 345, 379, 442, *0, 520, 542, 592, 622,* 642, 662, 692, 712, and 714.

UPPER YUKON BASIN.

Schrader, F. C., Reconnaissance on Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept., pt. 1, p. 485, 1900. (Coal at Tramway Bar, Koyukuk River.)

Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: Bull. 538, pp. 76–77, 1913. (Coal on Washington Creek.)

Maddren, A. G., The Koyukuk-Chandalar region, Alaska: Bull. 532, p. 56, 1913. (Coal on Dall River.)

Capps, S. R., The Chisana-White River district, Alaska: Bull. 630, pp. 125–126, 1916.

LOWER YUKON AND SEWARD PENINSULA.

Collier, A. J., Coal resources of the Yukon, Alaska: Bull. 218, 1903.

Smith, P. S., and Eakin, H. M., Geologic reconnaissance of southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. 449, pp. 136–141, 1911.

Harrington, G. L., The Anvik-Andreafski region, Alaska: Bull. 683, pp. 65–66, 1918.

Harrington, G. L., Gold and platinum placers of the Kiwalik-Koyuk region: Bull. 692, pp. 383–385, 399, 1917.

Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. 247, pp. 25–26, 67, 1905. (Chicago Creek coal.)

Henshaw, F. F., Mining in Fairhaven precinct: Bull. 379, pp. 362–363, 1909. (Chicago Creek coal mine.)

Collier, A. J., and Hess, F. L., Gold placers of parts of the Seward Peninsula: Bull. 328, pp. 83–85, 908. (Coal of Sinuk River basin and St. Lawrence Island.)

Cathcart, S. H., Mining in northwestern Alaska: Bull. 712, p. 196, 1920. (Coal at Unalaklik, Norton Sound.)

KUSKOKWIM BASIN.

Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper 70, p. 188, 1908. (Coal on Big River, a southerly tributary of the upper Kuskokwim.)

Maddren, A. G., Gold placers of the lower Kuskokwim: Bull. 622, p. 305, 1914. (Reported occurrence of coal on Eek and Kanektok rivers.)

Mertie, J. B., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region: Bull. 642, pp. 260–261, 1916.

Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: Bull. 655, pp. 154–156, 1917. (Coal near Iditarod.)

NORTHERN ALASKA.

Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper 20, pp. 106–114, 1904.

Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: Bull. 278, 1906.

Smith, P. S., The Noatak-Kobuk region, Alaska: Bull. 536, pp. 151–153, 1913.

MISCELLANEOUS OFFICIAL PUBLICATIONS.

Report on coal in Alaska for use in United States Navy: 63d Cong., 2d sess., H. Doc. 876, 1914. (Contains results of naval test of Bering River coal.)

Experimental tests of Matanuska coal for naval ships: 64th Cong., 1st sess., S. Doc. 26, 1915.

Reports of Alaskan Engineering Commission for the period from March 12, 1914, to December 31, 1915: 64th Cong., 1st sess., S. Doc. 610, pt. 2, p. 144, 1916. (Contains statements on cost of mining and transporting Matanuska and Bering River coal.)

Regulations governing coal-land leases in the Territory of Alaska, approved May 18, 1916, Dept. Interior, 1916.

Matanuska coal field, showing leasing units, Government reservation and topographic township plats, Alaska, Dept. Interior, 1916. (Maps.)

Bering River coal field, showing leasing units, Government reservation and topographic township plats, Alaska, Dept. Interior, 1916. (Maps.)

General information regarding lands offered for leasing in the Nenana coal field, Dept. Interior, 1918.

AVAILABILITY OF THE DEPOSITS.

The value of a coal deposit depends primarily on quality, quantity, cost of mining, cost of transportation, and markets. It is evident that the last three factors will vary with changing industrial conditions. The quality of a coal is fixed, but its value may also vary with changing conditions. A lignite that has no value for export may find a market with the development of metal mining or some other local industry. Measured by these considerations much of the Alaska coal has no present value, though it must be included in the ultimate coal reserves of the world. The coal without present importance comprises that which is inaccessible, that which is of too low grade to be exported and has no local market, and some of the high-grade coals in the accessible fields which are so folded and broken as to prohibit profitable exploitation under present conditions of cost and market.

The largest areas of inaccessible coals are those on the Arctic slope, where there are believed to be extensive coal fields. The coals are chiefly of low grade but include some excellent bituminous coals. Most of these coals are not now available, but some of them near Cape Lisburne might possibly be developed in a small way for use at Nome and in other parts of Seward Peninsula. On account of the shortness of the shipping season, however, this would be a doubtful venture. With these unavailable reserves should also be included much of the widely distributed lignite of Alaska, which if mined can supply only small local markets.

The enormous reserves of lignitic coal found in the Nenana and Cook Inlet fields, which are accessible, can not contribute much to the building up of a coal-mining industry, for under present methods of utilization they are not of good enough quality to find an export market and may not even compete in the local markets with the higher-grade Alaska coals.

The third group of unavailable coals includes those portions of the high-grade fuels of the Bering River and Matanuska fields which are so folded and broken as to make profitable exploitation under the present conditions of the coal market impossible. Though the surface outcrops in both these fields have been examined in great detail, yet definite determination of the quantity of coal now available for mining can be made only by underground explorations.

There are some fair bituminous coals at Chignik and Herendeen Bay, on Alaska Peninsula, which might find a small local market.

Alaska's annual coal consumption is now only about 165,000 tons, of which 60,000 tons is produced in the Territory. (See p. 74.) Even with a great expansion of territorial industries the local coal market will not be large enough to support more than a small coal-mining industry. Therefore the only hope of extensive mining is to furnish an export trade, and for this only the coals of the Bering River and Matanuska fields are of good enough quality. In both these fields high-grade bituminous steaming and coking coals have been found, as well as some anthracite. The bituminous coal is the best on the Pacific border of North America, and as much of it as can be mined at anything near a reasonable cost will find a ready export market. The possibility of using this coal for trans-Pacific shipping by a coaling station located on the great circle sailing route in the Aleutian Islands deserves consideration.

The Alaska coal-bearing areas that are accessible or can be early made accessible are listed in the following table. In the first figure column are given the areas of land which are pretty definitely known to contain coal beds, though it remains to be determined by underground exploration what part of them can now be profitably exploited. This table also contains estimates of the areas of the formations that are locally coal bearing in each of the more or less accessible fields.

Available coal fields of Alaska.

High-grade bituminous coal and anthracite.

Field or locality.	Area of probable coal lands (square miles).	Area of formations locally coal bearing (square miles).	Notes.
Matanuska	26	(?)	A part of this high-grade coal, suitable for export, is too much folded and broken to permit profitable exploitation at present.
Bering River	46	(?)	
Cape Lisburne (Arctic coast)	14	(?)	Accessible less than 2 months in the year.
	86		

Bituminous and subbituminous coals.

Field or locality.	Area of probable coal lands (square miles).	Area of formations locally coal bearing (square miles).	Notes.
Matanuska	22	....	Valuable for use in Alaska.
Alaska Peninsula	66	500	Present local market very small.
Yukon River	162	600	Local market very small.
Corwin (Arctic coast)	200	Large.	Accessible less than 2 months in the year.
	450	1,100	

Lignite.

Field or locality.	Area of probable coal lands (square miles).	Area of formations locally coal bearing (square miles).	Notes.
Cook Inlet	460	5,000	Includes an enormous tonnage of lignite, but of no present value for export.
Susitna Basin	30	1,000	Coal found at many localities under gravel cover. Valuable for local use only.
Nenana	120	600	Includes an enormous tonnage of lignite. Valuable for local use only.
Seward Peninsula and Norton Bay.	50	170	Available only for local use.
	660	6,770	

The above table shows that the accessible reserves of Alaska lignite are ample for all demands that can now be foreseen. Also that the lignitic and low-grade bituminous coals are widely distributed and can be exploited for local use at many localities. The quantity of lignitic coal that will be mined will be determined by the local demand, which in the immediate future will probably not exceed 50,000 to 100,000 tons a year, and this quantity will probably be distributed among several small mines.

The Nenana coal field will supply Fairbanks and other inland gold districts. Some lignitic coal will continue to be mined in the Cook Inlet region to supply local industries, but it may now find a strong competitor in the better coals from the Matanuska and Alaska Peninsula fields. Small quantities of lignitic coal will also be mined for local use in the Susitna basin, on Yukon River, in Seward Peninsula, and in the Norton Bay region. It is possible that the higher-grade coals of the Cape Lisburne region might be profitably mined for use on Seward Peninsula when gold placer mining revives on a large scale. The shortness of the shipping season, less than two months, has thus far discouraged such development and may prove an insurmountable obstacle.

The only exportable coal in Alaska is that of the Matanuska and Bering River fields. In both these fields very high grade coals, both bituminous and anthracite, have been found. Unfortunately the quality of the coal seems to be more or less directly proportional to the amount of deformation that the coal beds have undergone—that is, the best coal occurs in the most highly folded and broken beds and is the most difficult to mine.

One mine has been opened on a considerable scale near the west end of the Bering River field. This mine is at present difficult of access, but it could be connected with the Copper River Railroad by a branch line about 38 miles long. Such a branch would give connection over very easy grades with a good harbor at Cordova. Some work has also been done at a coal mine in the eastern part of the Bering River field, where the coal is semianthracite. This mine is connected by a railroad, now partly out of repair, with tidewater on the lower reaches of Bering River. Some small test shipments of semianthracite have been made from this mine.

The Alaskan Engineering Commission has opened two mines in the Matanuska field, both on the railroad. A little development work has also been done on some other properties in this field. The largest of the two mines is at Eska, where the coal is a low-grade bituminous coal, and from this mine the Engineering Commission and the towns of Anchorage and Seward are supplied with fuel. These operations show that the Eska coal can be mined on a commercial scale. At the other mine, at Chickaloon, some coal of very high

grade has been produced, but the operations are still in a more or less experimental stage, because the irregularities in the coal beds make mining very expensive.

In the opinion of the writer coal tracts that can be mined under present industrial conditions will be found in both the Matanuska and the Bering River fields. To select such tracts, however, will require more underground testing than has thus far been done. There can be no question that high-grade coal will be produced in both fields, yet the localities where the most favorable underground conditions exist still remain to be determined. The present developments give assurance that there is sufficient tonnage for all local needs, but it is not yet definitely established that there are coal reserves from which a large tonnage can be mined for export. The quality of the high-grade coals from these fields leaves little to be desired, though here, as in many other coal fields, washing of the product will be necessary.

There has been a little mining of lignitic coal at various places in Alaska since 1888. It was not, however, until the high quality of the Bering River and Matanuska coal was established by both public and private surveys and examinations, made between 1898 and 1905, that these northern coal fields excited any special interest. An Alaska coal-land law was enacted in 1904, but it proved, as interpreted, ineffective in encouraging mining development, nor did the supplementary legislation of 1908 serve to improve the situation.[53] Meanwhile, all Alaska coal lands were withdrawn from entry by Executive order dated November 12, 1906. Many coal claims were staked previous to this withdrawal, but patent was refused to all except a few that were isolated and too small in area to permit economic exploitation.

The Alaska coal situation was further embarrassed by the rapid increase in the petroleum output of California. As a result, the shortage of fuel on the Pacific seaboard that was threatening at the time of the first attempted development of Alaska bituminous coal was changed to an excess of production. The net result of these conditions was to prevent all coal-mining development in Alaska and to force Alaskan industries to draw on foreign sources for fuel.[54] Furthermore, the projects for private railroad construction to the coal fields were necessarily abandoned. The logic of the situation forced the Government to enter the field of railroad construction and also to undertake the underground exploration of the coal fields at public expense.

[53] Brooks, A. H., Alaska coal and its utilization: U. S. Geol. Survey Bull. 442, pp. 62-66, 1911.

[54] All Alaska oil lands were withdrawn in 1910. (See p. 53.)

The long and bitter controversy regarding an Alaska coal-land policy ended in 1914 with the enactment of a leasing law. As a consequence of the relative decrease in the market for coal, because of the large use of petroleum and the unsettled financial conditions brought about by the war, no great eagerness has been shown by capitalists to enter upon the development of the Alaska coal fields. Furthermore, the little underground work thus far done has more than confirmed the incomplete evidence obtained from surface exposures as to the greatly folded and broken condition of the coal beds in both the important fields. Most American coal mining has been done on beds that are but little disturbed. Hence those engaged in the industry have had little experience in the exploitation of greatly disturbed coal beds such as those of Alaska, which are, however, comparable to some of those mined in France and Belgium. Many have also contended that the terms of the coal leases are not sufficiently liberal, in view of the isolation and unprospected condition of the Alaska field. As a result of these conditions only one considerable coal-mining operation under leasehold is under way, and this has not yet reached a productive stage.

Between 1899 and 1919 Alaska mines produced a total of 243,677 tons of coal, of which 190,000 tons is the output of the last three years and is chiefly from the Government mines. During the same two decades the Territory has consumed a total of 2,411,947 tons of coal. Of this amount 1,276,600 tons has been imported from the Vancouver fields in British Columbia. (See p. 74.)

The market for these high-grade bituminous fuels is ample to absorb all the coal that can be produced for a number of years to come. The coal consumption of the Pacific Coast States and Alaska, exclusive of that used on railroads and steamers, is now about 3,200,000 tons annually, of which 200,000 to 300,000 tons is imported from British Columbia. Railroads in the Pacific Coast States consume about 2,000,000 tons, practically all used in Washington. The bunker coal supplied to steamers at American Pacific ports amounted to 343,000 tons in 1915 and 474,000 tons in 1918.[55] This bunker trade is one for which the Alaska coals are especially well suited. Some of the Alaska coals are also well adapted for coking. About 200,000 tons of coking coal is used in the Pacific Coast States. Of the Pacific coast coals only those from Alaska are of sufficiently high grade to be suitable for Navy use. An estimate of the needs of the Navy at 200,000 tons, of Alaska at 100,000 tons, and of coking coal at 200,000 tons would give a certain market for 500,000 tons. In addition to this the Alaska fuel should be a strong competitor in the bunker trade. Furthermore, the increased cost of petroleum will

[55] Brooks, A. H., U. S. Geol. Survey Bull. 662, pp. 25–30, 1917.

soon enlarge the market for coal on the Pacific seaboard. One adverse factor that should be considered is the competition of the high-grade Alaska coals with those from the East brought through the Panama Canal. Owing to the physical conditions under which the eastern bituminous coals occur they are cheaper to mine than those in Alaska, and another advantage lies in the more favorable industrial conditions. It is probably safe to assume, however, that even under this competition Alaska coal should have a market for at least 1,000,000 tons. Whether any such production can be reached in the immediate future can be determined only by further prospecting.

PEAT.[56]

Peat is found in nearly every part of Alaska except in the high ranges. The humidity of the Pacific coastal zone and the consequent luxuriant vegetation favor the accumulation of peat. Southeastern Alaska is heavily forested, and much of it has a dense growth of underbrush with a flooring of moss. In southwestern Alaska timber is entirely absent, but all the lowland and much of the upland area are covered with moss, grass, and small shrubbery. The prevailing humidity in both these regions favors the accumulation of vegetable refuse. Though there has been no prospecting for peat in this part of the Territory, deposits at least 15 to 20 feet thick are known and are believed to be of good quality.

Central and northern Alaska have a much smaller precipitation. Here, however, the soil is nearly everywhere mantled by a dense blanket of moss and other vegetation. This is especially striking in the extensive timberless areas of tundra which lie along Bering Sea and the Arctic Ocean. In these two provinces the subsoil is usually frozen, so that the waters are retained at the surface. The moss, except in excessively dry weather, is usually saturated with water. All these conditions, which promote vegetable growth and retard evaporation and oxidation, are favorable to the formation of peat. As a matter of fact, there is nearly everywhere a layer of peaty material underneath the soil. In some natural exposures in these provinces peat deposits having a depth of 30 to 40 feet have been observed. Although the widespread surface layer of peat is of an inferior quality, some of the deeper-lying beds are probably of high grade. There are no data whatever at hand to estimate the available supply of peat, but as it is found in every part of Alaska and on the great tundras of the north, occupying at least a quarter of the Territory and comprising layers of greater or less thickness, the supply must be enormous and possibly exceeds that of the entire United States.

[56] Brooks, A. H., Mineral resources of Alaska: U. S. Geol. Survey Bull. 394, pp. 188-189, 1909. Davis, C. A., The possible use of peat fuel in Alaska: U. S. Geol. Survey Bull. 379, pp. 53-66, 1909; The preparation and use of peat as fuel: U. S. Geol. Survey Bull. 442, pp. 101-132, 1910.

In the presence of more easily available fuel there has been no occasion to utilize any of the peat beds, so practically nothing is known of their fuel value, extent, or thickness, except what has been stated. One of the few deposits of this mineral fuel in Alaska that has been exploited is a peat bed saturated with petroleum residue near Cold Bay, on the Alaska Peninsula, where some years ago the material was used for fuel at the neighboring oil wells. Here, however, it is the petroleum residue rather than the peat which gives the deposit its chief value.

The peat deposits have at present no value, for lignitic and better-grade coals are too widely distributed to encourage the use of a less available fuel. Moreover, the time appears very remote when these peat deposits will be utilized, except at localities where coal is absent. Certainly recourse to the peat will take place only when the more valuable mineral fuels are not obtainable.

PETROLEUM.

As all the available data relating to the occurrences of oil in Alaska have been recently compiled and discussed by Martin,[57] the petroleum resources need only brief mention here. Petroleum seepages are known in five widely separated districts in Alaska and have been reported from a number of others. As drilling has been confined to one field, there are no data upon which to estimate petroleum reserves or possible output. The quality of Alaska petroleum leaves little to be desired. It is a high-grade refining oil similar in composition to that from Pennsylvania.

Oil seepages (see map, Pl. II, in pocket) are known at Katalla, near Controller Bay, 60 miles east of Cordova, and at Yakataga, 60 miles east of Katalla; near Iniskin Bay, on the west shore of Cook Inlet; and on the Alaska Peninsula, notably near Cold Bay. There is also a seepage near Douglas River, near the southwest shore of Cook Inlet, at the base of the Alaska Peninsula. More or less definite reports have been received as to the presence of seepages at other places in the Alaska Peninsula. If these reports are confirmed, they indicate a possible wide distribution of seepages in the Alaska Peninsula and consequently a rather large area in which wildcat drilling might be justified. The structure of the Katalla field is very complex, but the incomplete information at hand indicates that the folding is simpler at Yakataga, on Cook Inlet, and on the Alaska Peninsula. There has, however, been no detailed geologic mapping in the latter fields. All these districts are fairly accessible to ports on the Pacific, open to navigation throughout the year.

There are also indications of the presence of petroleum in the extreme northern part of Alaska, near Smith Bay, about 100 miles

[57] Martin, G. C., Preliminary report on the oil resources of Alaska: U. S. Geol. Survey Bull. 719 (in press).

southeast of Point Barrow. This area is entirely unknown geologically. To judge by the results of Schrader's exploration of the Colville River Basin,[58] 100 miles to the east, the structure is likely to be favorable for the presence of oil pools. The region is so inaccessible that capital is not likely to undertake its prospecting except under very liberal terms, both as regards size of leaseholds and royalties.

Martin has also listed a number of other isolated localities in Alaska where oil or gas seepages are known or reported and has presented the geologic evidence bearing on the possible presence of oil pools. His conclusions are largely adverse. The localities where oil or gas are reported include as widely separated localities as Admiralty Island and Cape Spencer, in southeastern Alaska; Seward, on Kenai Peninsula; Tyonek, on Cook Inlet; Nushagak, on Bristol Bay; and Healy Creek, in the Tanana Valley.

Alaska petroleum first attracted attention about 1898, when the Klondike excitement carried so many people North. Between 1901 and 1904 there was some drilling in the Iniskin and Cold Bay districts, and rather extensive operations were undertaken in the more accessible Katalla field. By 1906 most of the excitement had died down, owing largely to the rapid development of the California oil fields, which drew the speculative oil operators out of Alaska. In 1910 all the oil lands of Alaska were withdrawn from entry, so that no one could get title to any claims. Only in the Katalla field was any work continued, and there chiefly on one claim to which title had been earned previous to the withdrawal. It was the withdrawal of the oil lands that has checked nearly all prospecting during a decade and not any lack of promise in the Alaska fields.

The enactment of the oil leasing law in 1920, combined with the worldwide search for petroleum, has again attracted public attention to Alaska oil. Many claims have been staked, and preparations are being made to start drilling at several places in 1921. There is good reason to believe that productive oil fields will be developed, though there are no facts at hand to prove that startling discoveries will be made. It is certain, however, in view of the present relative scarcity of high-grade refining oil, that drilling is fully justified at a number of localities in Alaska. It is believed that petroleum is one of the resources that will help swell the value of the total mineral production of the Territory. In fact, it is the development of this resource which promises most for the relief of the present stagnation in Alaska mining. The search for oil will stimulate migration northward and will lead to the improvement of conditions of transportation, especially to some of the more isolated districts. Should drilling reveal commercial pools of petroleum a very early revival of the Alaska mining industry as a whole can be confidently predicted.

[58] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, 1904.

STRUCTURAL MATERIAL, ETC.

Nearly $2,000,000 worth of marble has been produced in Alaska since quarrying began in 1904, but all of this has come from the Ketchikan district of southeastern Alaska. Marble is widely distributed in southeastern Alaska,[59] and there are many undeveloped deposits that apparently carry commercial stone. The broken shore line, with its many harbors, and the water powers favor the marble industry in this field. It is to be expected that with the increased demand for marble in the States of the west coast the Alaska output will be greater.

Granite and granitic rocks, in part suitable for building stone, are also widely distributed in southeastern Alaska, but are undeveloped.

Gypsum has been mined for many years at Iyoukeen Cove, Chichagof Island, in the Sitka district.[60] Though no other gypsum deposits have been found there is no reason to believe that the geologic conditions by which the gypsum deposit was formed may not have been duplicated in other localities.

A promising deposit of barite was discovered by E. F. Burchard on Castle Island in Duncan Canal, near Wrangell, in 1913.[61] A rough estimate indicates that about 50,000 tons of barite is in sight above the level of tidewater. This deposit is not yet developed. A barite deposit at Lime Point, on the west side of Prince of Wales Island, near Sulzer, in the Ketchikan district, has been opened for a distance of 100 feet and is about 30 feet wide.[62] Some shipments of barite were made from this deposit in 1915 and 1916.

Clay is found in many parts of Alaska, but little is known of its quality. Some clay has been used for brickmaking at Anchorage. Limestones of varied composition are widely distributed in Alaska, notably in southeastern Alaska, in the Copper and Susitna River basins, in the Yukon Valley, and on Seward Peninsula. Lime for many purposes could be produced, should there be a local demand.

There are some deposits of pumice in the Alaska Peninsula and adjacent islands, the ejecta of Mount Katmai. The largest accessible deposits known are on the shores of Amalik Bay, on the east side of the peninsula, and these are 20 feet or more in thickness. Finer pumice or tuff is widely distributed over the north end of Kodiak Island, and a few shipments of this material for use as an abrasive have been made from this region. Graphite in considerable quantities has been found in the Kiwalik Mountains, 40 miles north of Nome but more accessible to the sea from Imuruk Basin, which is connected by tidal estuary with Port Clarence. The graphite in

[59] Burchard, E. F., Marble resources of southeastern Alaska: U. S. Geol. Survey Bull. 682, 1920.

[60] Brooks, A. H., U. S. Geol. Survey Bull. 542, pp. 50–51, 1913.

[61] Burchard, E. F., A barite deposit near Wrangell: U. S. Geol. Survey Bull. 592, pp. 109–117, 1914.

[62] Chapin, Theodore, Mining developments of southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 104, 1916.

this district occurs as lenses in quartz-biotite schists, which are themselves graphitic.[63] These deposits are of sufficient size to justify the hope that they can be profitably exploited, provided they can meet the competition with that from more accessible regions.

Sulphur deposits have been found in association with some of the volcanic rocks in southwestern Alaska.[64] A commercial deposit of sulphur is being opened on Akun Island, near the east end of the Aleutian chain. The reduction plant was to be installed in 1920, and the mine was then to be placed on a productive basis.

A little potash has been found in some of the shallow lakes on the flats of Yukon and Porcupine rivers, near Fort Yukon. Little is known about this occurrence, and there is no evidence that the quantity is sufficient to justify development, even for local use.

A few garnets have been mined near Wrangell, in southeastern Alaska, where, according to E. F. Burchard,[65] they occur in a mica schist. These garnets are not suitable for gems but may have value as abrasives.

Jade implements and ornaments have long been in wide circulation among the Alaska Eskimo. For many years it was believed that this jade all came from Asia, but it is now known that it came in part from the so-called Jade Mountains of the Kobuk River region.[66] Some of the so-called jade from this source has proved to be serpentine, some green quartzite, and some is nephrite, which commercially is classed as jade. Attempts to exploit these deposits have thus far been unsuccessful.

WATER.

Though water is to be counted among mineral resources its value to the mining industry is chiefly indirect by affording a source of power, and the largest use of water under hydrostatic head has been in placer mining. The richest of the Alaska placers lie in the interior and on Seward Peninsula, where water for mining is not abundant.[67] This scarcity is due to the small precipitation and the character of the topography, which gives low stream gradients. Hydraulic mining has therefore played no great part in the production of gold in Alaska. The chief operations have been in the Nizina district, of the Copper River basin. There are other localities in the Pacific slope region of Alaska where hydraulic mining will be undertaken.

[63] Harrington, G. L., Graphite mining in Seward Peninsula: U. S. Geol. Survey Bull. 692, pp. 363–367, 1919.

[64] Maddren, A. G., Sulphur on Unalaska and Akun islands and near Stepovak Bay: U. S. Geol. Survey Bull. 692, pp. 283–298, 1919.

[65] Brooks, A. H., The mining industry in 1912: U. S. Geol. Survey Bull. 542, p. 51, 1913.

[66] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 154–155, 1913.

[67] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula, Alaska: U. S. Geol. Survey Water-Supply Paper 314, 1913. Ellsworth, C. E., and Davenport, R. W., Surface water supply of the Yukon-Tanana region, Alaska: U. S. Geol. Survey Water-Supply Paper 342, 1915.

The largest water-power developments are in southeastern Alaska, including notably those for the mines of the Juneau district. Smaller projects for other industries have also been installed at several places along the Pacific seaboard. Other large undeveloped water powers occur in the panhandle of Alaska and in time will be utilized for wood-pulp and other industries.

There are but few power developments in the Copper River, Prince William Sound, and Cook Inlet and Susitna basins. Little is known about the water powers of this province, but a reconnaissance [68] made some years ago shows that they are worthy of further investigation. There are also some water powers in the Iliamna Lake region, in the Alaska Range, and in other parts of the Territory about which little is known.

Mineral and hot springs are widely distributed in Alaska.[69] Some years ago an attempt was made to develop a mineral spring in southeastern Alaska, and bottled water from it was put on the market but met with failure. It is not known whether the water in any of the Alaska mineral springs is of a sufficiently distinctive composition to justify its development as a potable water. The hot springs have, however, played a somewhat important part in the hygienic life of the people.

SUMMARY AND CONCLUSIONS.

It has been shown that the value of Alaska's gold placer reserves is greater than that of the placer gold that has been produced during 40 years of mining; also that the future of the gold-mining industry depends as much on the improvement of the general industrial conditions as on the construction of railroads and wagon roads and improvements in steamship service. Lode gold mining in Alaska is at present on the wane, because the largest auriferous lode mines, those in the Juneau district, have been working on so low a margin of profit that they can not all hope to continue under present industrial conditions. On the other hand, auriferous lodes are known to be widely distributed in Alaska and it is certain that they will be developed when means of communication are bettered and industrial conditions improve.

Alaska's copper production of the past has been based chiefly on the output of a few mines operating on very rich ores. Smaller mines on the coast have been hampered by lack of shipping and smelter capacity. Copper ore is widely distributed in the Territory. The mining of copper will continue to increase if transportation rates are lowered, and the Territory will long be an important source of copper.

Silver-lead ores are widely distributed, but no large deposits have been found. Tin deposits have been found in several localities, but

[68] Ellsworth, C. E., and Davenport, R. W., A water-power reconnaissance in South-central Alaska: U. S. Geol. Survey Water-Supply Paper 372, 1915.

[69] Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, 1917.

the outlook for any large increase of the tin output on the basis of the deposits now known is not hopeful. Only one deposit of the metals of the platinum group has been found that gives promise of making any considerable output. Quicksilver, in the form of cinnabar, has been developed in only one district and that only on a small scale. Nickel-bearing ores have been found at three localities, but the evidence in hand does not justify an opinion on the future of the nickel-mining industry. The known deposits of chromite, tungsten, antimony, and molybdenite seem to justify the hope of an output of these metals, provided there is a market for them. Little is known of Alaska iron ores, but there is reason to believe that some of the deposits of this metal will be utilized when an iron and steel making industry develops on the Pacific coast.

The deposits of lignitic coal in Alaska are much more than sufficient to supply all future local needs. Alaska also contains the best high-grade bituminous coal on the Pacific seaboard. It seems probable that an export trade in these fuels will be developed, though the cost of mining will be high on account of their mode of occurrence. The evidence of petroleum in Alaska justifies the opinion that an oil-producing industry will be developed.

Alaska also contains a great variety of other mineral deposits, many of which have been more or less developed. Although the output from such deposits will probably be small compared with that of the gold, copper, coal, and petroleum, yet it will help to swell the total value of Alaska's mineral products.

The foregoing summary indicates that the Alaska mining industry has a most promising outlook and that the mineral output of the past is but a small fraction of that which will be produced in the future. It is not to be denied, however, that the immediate prospect for a large expansion of Alaska mining is not so hopeful. Alaska's great gold reserves must to a large degree lie dormant until the changes in economic conditions give better assurance than now exists of profitable ventures. Nor will the present price of copper encourage an expansion of the copper-mining industry.

Coal mining has only begun, and much underground exploration must be done before a large expansion is assured. The testing of the oil fields awaits the driller but will probably be undertaken at once.

Aside from the improvement in general and worldwide economic conditions, what the Alaska mining industry most needs is a lowering of costs of transportation, including not only reduction of the rates on existing lines but the expansion of land and water routes, including the construction of roads and trails.

THE ALASKAN MINING INDUSTRY IN 1919.

By Alfred H. Brooks and George C. Martin.

GENERAL STATEMENT.

Gold and copper mining have always been the principal mineral industries of Alaska, and in 1919 both were subject to great depression throughout the world. Hence the value of Alaska's mineral output decreased from $28,253,961 in 1918 to $19,620,913 in 1919, when it was the lowest for any one year since 1914. Stimulated by the high price of copper during the war, Alaska made an enormous output of copper, which was chiefly the product of three large mines. With the fall in the price of copper (see fig. 1) the Alaska copper industry reverted to more normal pre-war conditions. Meanwhile the world-wide depression in gold mining consequent upon high operating costs brought on by the war has seriously crippled gold mining in Alaska. As a consequence of the increase in costs the value of the annual output of gold from Alaska declined from $16,700,000 in 1916 to $9,426,000 in 1919. The Alaska gold-mining industry is particularly sensitive to present conditions because many of the enterprises were not on a very sound economic basis. Gold production has been kept up for many years by the exploitation of bonanza placers rather than by the systematic development of large deposits of lower grade. The mining of placer gold has been carried on as a gamble rather than as a business venture. As the purchasing power of their product was reduced many gold-mining operators have been attracted to other fields, such as oil drilling in the States, in which the chances of large speculative profits were greater than in placer mining. It is especially unfortunate that all but one of the large quartz gold-mining ventures in Alaska are the lode mines near Juneau, where the margin of profit is so small that the increased cost of operation due to the war has imperiled the success of the undertakings.

The outlook for gold mining in Alaska under present economic conditions is not hopeful, yet the continued success of certain larger operations, like dredging, shows that it is by no means hopeless, and such operations and the mining of bonanza deposits will no doubt be continued. Alaska still contains large reserves of gold-bearing gravels (see pp. 9–11) that can be mined profitably when transportation and industrial conditions are improved. No one can foretell whether any more bonanza camps will be found, and therefore the only certain future success lies in the development of deposits of lower grade.

The large demand for tungsten, antimony, and chromite during the war greatly stimulated the search for and mining of ores carrying these metals. Valuable deposits of these ores were found and mined, and mining of them will in time be renewed, though it is not justified by the present demand because of the high cost of operation and transportation.

Alaska has not yet recovered from the interdict placed on the development of mineral fuels by the withdrawal from entry of the coal lands in 1906 and of the oil lands in 1910. The leasing law of 1913 opened up the coal fields, but some of its provisions appear to be not liberal enough to encourage large developments. In 1920 an oil-land leasing act was passed, and this will no doubt lead to development and eventually to oil production.

The greatest need of the Alaska mining industry is cheaper and better land and water transportation. This need calls for the completion of the railroad, the building of wagon roads, and the lowering of ocean and river freight and passenger rates. Yet, except for the work done on the railroad and on the construction of wagon roads and trails, practically no advance was made in 1919, and, indeed, the transportation conditions have been the worst in many years. Ocean freight and passenger rates have been increased and the service has been decreased. The Yukon River steamer service in 1919 was very inadequate. The most important event of the year for the future of mining in the Territory was the continuation of the work on the Government railroad and the assurance by congressional action of the money needed to complete the line. It is now certain that in three years there will be a standard-gage railway connecting tidewater on the Pacific with Fairbanks and navigable waters on the Yukon. To give its full benefit to the mining industry, however, the Alaska Railroad must be connected with mining centers by good wagon roads.

Mineral output of Alaska, 1918 and 1919.

	1918		1919		Decrease or increase in 1919.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold............fine ounces..	458,641	$9,480,952	455,984	$9,426,032	− 2,657	− $54,920
Copper.............pounds..	69,224,951	17,098,563	47,220,771	8,783,063	−22,004,180	−8,315,500
Silver...........fine ounces..	847,789	847,789	629,708	705,273	− 218,081	− 142,516
Coal.............short tons..	75,606	411,850	60,674	343,547	− 14,932	− 68,303
Tin, metallic..........do....	68	118,000	56	73,400	− 12	− 44,600
Lead..................do....	564	80,088	687	72,822	+ 123	− 7,266
Miscellaneous metallic products, including palladium and platinum............	....	[a] 96,100	....	[b] 73,663	....	− 22,437
Miscellaneous nonmetallic products, including petroleum, marble, and gypsum................	....	[c] 120,619	....	143,113	....	+ 22,494
	....	28,253,961	....	19,620,913	....	−8,633,048

[a] Included chrome ore, tungsten, antimony, platinum, and palladium in 1918.
[b] Palladium and platinum only in 1919.
[c] Included lime in 1918.

Regular mining in Alaska may be said to have begun in 1880, when the Juneau gold placers were first exploited. It is estimated that since that time Alaska has produced mineral wealth to the value of more than $438,000,000.

Value of total mineral production of Alaska, 1880–1919.

By years.				By substances.	
1880-1890	$4,686,714	1906	$23,378,428	Gold	$311,664,993
1891	916,920	1907	20,850,235	Copper	114,526,096
1892	1,098,400	1908	20,145,632	Silver	6,303,528
1893	1,051,610	1909	21,146,953	Coal	1,440,460
1894	1,312,567	1910	16,887,244	Tin	918,152
1895	2,388,042	1911	20,691,241	Lead	522,258
1896	2,981,877	1912	22,536,849	Antimony	237,500
1897	2,540,401	1913	19,476,356	Marble, gypsum, petroleum, etc.	2,548,079
1898	2,587,815	1914	19,065,666		438,161,066
1899	5,706,226	1915	32,854,229		
1900	8,241,734	1916	48,632,212		
1901	7,010,838	1917	40,710,205		
1902	8,403,153	1918	28,253,961		
1903	8,944,134	1919	19,620,913		
1904	9,569,715		438,171,032		
1905	16,480,762				

DISCOVERIES AND NEW DEVELOPMENTS.

The most notable mining advances during the year were those made near McGrath, in the Georgetown district of the middle Kuskokwim region. Here a gold dredge, installed in 1918, was operated during the entire season, but more significant was the discovery of numerous gold-bearing ledges which give promise of being of commercial importance. The discovery of a valuable silver-bearing galena lode in the Kantishna district drew many prospectors to this little-known part of Alaska. Still greater excitement was caused by the development of rich deposits of gold and silver in the Canadian part of the Portland Canal district. (See pp. 129–142.) Some of these deposits are readily accessible only through Alaska. The town of Hyder, on Portland Canal, was established on the Alaska side of the boundary to serve this district, and from Hyder a road has been built to the Canadian mines. Prospecting has been done in the Alaska part of the Portland Canal district, but so far as known no ore bodies of proved commercial value have been developed.

Many oil claims are now being staked under the oil-leasing law of 1920. Coal was mined in 1919 in the Matanuska field for the use of the Alaskan Engineering Commission and for the town of Anchorage. Systematic prospecting of a group of claims held under lease in the Bering River coal field was underway in 1919. The railroad connection of the Nenana lignite field with the town of Fairbanks, established in 1919 (except for a bridge at Tanana River), has stimulated systematic prospecting.

GOLD AND SILVER.

TOTAL PRODUCTION.

The following table gives an estimate of the total production of gold and silver since the beginning of mining in 1880. For the earlier years the figures, especially those for silver, are probably far from correct, but they are based on the best information now available.

Gold and silver produced in Alaska, 1880–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Commercial value.
1880	967	$20,000		
1881	1,935	40,000		
1882	7,256	150,000		
1883	14,561	301,000		
1884	9,724	201,000	10,320	$11,146
1885	14,512	300,000		
1886	21,575	446,000		
1887	32,653	675,000		
1888	41,119	850,000	2,320	2,181
1889	43,538	900,000	8,000	7,490
1890	36,862	762,000	7,500	6,071
1891	43,538	900,000	8,000	7,920
1892	52,245	1,080,000	8,000	7,000
1893	50,213	1,038,000	8,400	6,570
1894	62,017	1,282,000	22,261	14,257
1895	112,642	2,328,500	67,200	44,222
1896	138,401	2,861,000	145,300	99,087
1897	118,011	2,439,500	116,400	70,741
1898	121,760	2,517,000	92,400	54,575
1899	270,997	5,602,000	140,100	84,276
1900	395,030	8,166,000	73,300	45,494
1901	335,369	6,932,700	47,900	28,598
1902	400,709	8,283,400	92,000	48,590
1903	420,069	8,683,600	143,600	77,843
1904	443,115	9,160,000	198,700	114,934
1905	756,101	15,630,000	132,174	80,165
1906	1,066,030	22,036,794	203,500	136,345
1907	936,043	19,349,743	149,784	98,857
1908	933,290	19,292,818	135,672	71,906
1909	987,417	20,411,716	147,950	76,934
1910	780,131	16,126,749	157,850	85,239
1911	815,276	16,853,256	460,231	243,923
1912	829,436	17,145,951	515,186	316,839
1913	755,947	15,626,813	362,563	218,988
1914	762,596	15,764,259	394,805	218,327
1915	807,966	16,702,144	1,071,782	543,393
1916	834,068	17,241,713	1,379,171	907,495
1917	709,049	14,657,353	1,239,150	1,021,060
1918	458,641	9,480,952	847,789	847,789
1919	455,984	9,426,032	629,708	705,273
	15,076,793	311,664,993	9,019,016	6,303,528

The subjoined table gives an estimate, based on the best available data, of the gold and silver produced in Alaska from different sources since mining began in 1880. About $65,100,000 worth of gold, or about one-fifth of the total estimated output, was produced before 1905, and there is but scant information about its source. For the period since that time fairly complete statistical returns are available, and it is probable that the figures presented in the following table are sufficiently accurate to be valuable. The figures given for the silver recovered from placer gold and from siliceous ores

are probably less accurate than those for the gold. Copper mining did not begin in Alaska until 1901, and the figures for gold and silver derived from this industry, as now presented, are therefore a close approximation to the actual output.

Gold and silver produced in Alaska from different sources, 1880–1919.

	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Siliceous ores [a]	4,446,528	$91,917,907	1,428,580	$1,053,130
Copper ores	83,886	1,734,094	5,815,886	4,213,418
Placers	10,546,379	218,012,992	1,774,550	1,036,980
	15,076,793	311,664,993	9,019,016	6,303,528

[a] Including small amounts of lead ore.

The above table shows that about 29.5 per cent of the total gold produced in Alaska has been obtained from siliceous ores mined from auriferous lodes. In 1919 the lode-gold production was 46.6 per cent; in 1918, 36.6 per cent; in 1917, 31 per cent; in 1916, 38 per cent; in 1915, 37 per cent; in 1914, 32 per cent; in 1913, 31.6 per cent; and in 1912, 29 per cent. In the following table the production of precious metals in 1919 has been distributed as to sources:

Gold and silver produced in Alaska, 1919, by sources.

Source.	Ore (tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Siliceous ores	3,262,573	212,474	$4,392,237	108,691	$121,734
Copper ores	492,644	3,086	63,795	488,034	546,598
Placers	....	240,424	4,970,000	32,983	36,941
	3,755,217	455,984	9,426,032	629,708	705,273

LODE MINING.

Twenty-three gold-lode mines and two prospects were operated in Alaska in 1919 and produced gold worth about $4,392,237. Twenty-five mines were operated in 1918 and produced gold worth $3,473,317. The increase in 1919 came from the four large mines in the Juneau and Sitka districts. The increased production at Juneau does not assure the continued prosperity of the lode-mining industry, for these mines are working on too small a margin between the value of gold recovered and the cost of operation to make it certain that they will be able to pay the continually increasing expense of mining. The only other large gold-lode mine in Alaska is in the Sitka district,

where operations in 1919 were on a somewhat larger scale than in 1918.

Of the producing mines, seven were in southeastern Alaska, one in the Copper River district, three on Kenai Peninsula, five in the Willow Creek district, six in the Fairbanks district, and one on Seward Peninsula. In 1919 the average value of the gold and silver contents for all siliceous ores mined was $1.38 a ton; the average for 1918 was $1.70 a ton. These averages reflect the dominance in the total lode production of the large tonnage produced from the low-grade ores of the Juneau district.

The production, by districts, of gold and silver in 1918 from gold-lode mines is given in the following table:

Gold and silver produced from gold-lode mines in Alaska, 1919, by districts.

District.	Mines operated.	Ore mined (short tons).	Gold.		Silver.		Average value for ton of ore in gold and silver.
			Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.	
Southeastern Alaska	[a] 7	3,253,848	201,937	$4,174,407	107,359	$120,242	$1.32
Kenai Peninsula	3	96	435	8,987	284	318	96.93
Willow Creek	5	6,730	7,882	162,944	508	569	24.30
Fairbanks district	6	1,384	2,027	41,893	378	424	30.58
Other districts [b]	2	515	193	4,006	162	181	8.13
	23	3,262,573	212,474	4,392,237	108,691	121,734	1.38

[a] Also shipment from one prospect.
[b] Includes 1 mine in the Copper River district and 1 in Seward Peninsula; also 1 prospect on Prince William Sound.

The prospecting and development of gold lodes in 1919 was most active in the Willow Creek district, which lies adjacent to the railroad, but where no property has yet been opened up and equipped on a large scale. There is good reason to believe that lode mining in the Willow Creek district will make substantial gains in 1920. At Fairbanks lode mining and prospecting have almost ceased, the only operations being those of a few owners who continue a little development with the plan of blocking out ore to be mined when the railroad is completed. Incidental to this work a little ore is recovered and milled, and there are many small auriferous lodes in the Fairbanks district which can be profitably exploited when the economic conditions improve. Comparatively little work was done on the lodes of Seward Peninsula in 1919. A gold-lode mine near Bluff was operated and made a small output, and some ore was mined but not shipped from the silver-lead prospect on Kugruk River.

PLACER MINING.

During 39 years of mining Alaska has produced gold to the value of more than $311,000,000, and $218,000,000 of this amount is to be

credited to her placer mines. For reasons already discussed there was less placer mining in 1919 than in 1918, and the outlook for a revival of the industry as a whole under present economic conditions is not hopeful. In the following table a comparison is made between the placer-mining industry in 1919 and in 1918:

Alaska placer mining in 1918 and 1919.

	Summer.		Winter.		Value of output.
	Mines.	Miners.	Mines.	Miners.	
1918	574	3,000	153	613	$5,900,000
1919	466	2,177	88	318	4,970,000
Decrease	108	823	65	295	930,000

A most unfortunate effect of the decline in the production of gold, especially by placer mining, is the discouragement of the prospector. Though many prospectors devote their attention to the search for copper and other minerals, prospectors as a class are held to their vocation by the hope of finding rich placers which they can develop by individual effort. The loss of over 1,100 men in the placer-mining industry, as shown by the above table, means the loss of an equal number of at least potential prospectors. Many prospectors have been drawn away from Alaska by the high wages and good business opportunities which war conditions have created in the States. It is, indeed, no longer necessary to go to Alaska to obtain high wages. As a consequence probably half, possibly three-quarters, of the prewar Alaska prospectors have sought other fields.

The value of the placer-gold output of Alaska decreased from $5,900,000 in 1918 to $4,970,000 in 1919, and the output will be less in 1920. The decrease was general for all Alaska districts except for some in the Seward Peninsula and the Kuskokwim regions. It is largely due to conditions that affect gold mining adversely throughout Alaska. Shortage of labor, lack of transportation, and unfavorable seasonal climatic conditions have also operated to curtail the placer-gold output of certain districts. The depletion of bonanza placers also helped to decrease placer mining. No important discoveries of placer gold were made during the year, and there was a marked decrease in prospecting for placer gold.

About 466 placer mines were operated in the summer of 1919 and 88 during the previous winter, but many for only a part of the season. About 2,177 men were engaged in productive placer mining in the summer and 318 in the winter. In addition several hundred men were engaged in prospecting or other nonproductive work relating to

placer mining. No important new placer-bearing areas were discovered in 1919. The output and operations of placer mines in 1919, by regions, are shown in the following table:

Gold and silver produced from placer mines in Alaska, 1919, by regions.

Region.	Gold.		Silver.		Gravel handled (cubic yards).	Recovery per cubic yard.	Number of mines.		Number of miners.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.			Summer.	Winter.	Summer.	Winter.
Southeastern Alaska	1,209.37	$25,000	204	$229	20,000	$1.26	9	......	29	......
Copper River region	8,949.38	185,000	912	1,021	340,000	.55	18	......	115	......
Cook Inlet and Susitna region	5,321.25	110,000	827	926	191,000	.58	21	......	81	......
Southwestern Alaska	241.88	5,000	22	25	3,000	1.67	5	......	10	......
Yukon basin	140,771.25	2,910,000	19,461	21,796	1,616,000	1.81	274	76	1,246	255
Kuskokwim region	16,931.25	350,000	4,431	4,963	205,000	1.73	20	2	101	3
Seward Peninsula	65,790.00	1,360,000	6,940	7,773	2,165,000	.63	103	10	555	60
Kobuk region	1,209.37	25,000	186	208	8,000	3.15	16	......	40	......
	240,423.75	4,970,000	32,983	36,941	4,548,000	1.10	466	88	2,177	318

The following table shows approximately the total bulk of gravel mined annually since 1907 and the value of the gold recovered per cubic yard. This table is based in part on returns made by placer-mine operators and in part on known facts or assumptions concerning the richness of the gravels in the several districts. Although the table is thus in part an estimate it is probably nearly correct.

Gravel sluiced in Alaskan placer mines and value of gold recovered, 1908–1919.

Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.	Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.
1908	4,275,000	$3.74	1914	8,500,000	$1.26
1909	4,418,000	3.66	1915	8,100,000	1.29
1910	4,036,000	2.97	1916	7,100,000	1.57
1911	5,790,000	2.17	1917	7,000,000	1.40
1912	7,050,000	1.70	1918	4,931,000	1.20
1913	6,800,000	1.57	1919	4,548,000	1.10

The table shows that from 1908 to 1914 there was a decline in the average gold content of the gravels mined. This decline reflects the improved methods of placer mining that have been introduced, more especially the increase in the use of dredges, which is brought out in the following table:

Relation of recovery of placer gold per cubic yard to proportion produced by dredges.

	Percentage of placer gold produced by dredges.	Recovery per cubic yard.		
		Dredges.	Mines.	All placers.
1911	12	$0.60	$3.36	$2.17
1912	18	.65	2.68	1.70
1913	21	.54	3.11	1.57
1914	22	.53	2.07	1.26
1915	22	.51	2.33	1.29
1916	24	.69	2.64	1.57
1917	26	.68	2.21	1.40
1918	24	.57	1.84	1.20
1919	27	.67	1.31	1.10

Gold dredging continues to hold an important place in Alaska placer mining. In 1919 there were 28 dredges in operation for the whole or part of the season and they produced gold to the value of about $1,360,000, compared with $1,425,000 worth of gold produced by 28 dredges in 1918. Two of these dredges were operated in 1919 in the Fairbanks district, 2 in the Iditarod district, 1 in the Birch Creek district of the Yukon basin, 1 in the Mount McKinley (McGrath) district of the Kuskokwim basin, and 22 on Seward Peninsula. These dredges handled about 1,760,000 cubic yards of gravel, compared with about 2,490,000 cubic yards of gravel handled in 1918. The average recovery of gold per cubic yard was about 67 cents in 1919 and 57 cents in 1918. The gold dredges of Seward Peninsula produced gold worth $450,000 from about 865,000 cubic yards of gravel, making an average recovery of 52 cents a cubic yard in 1919 compared with 40 cents a cubic yard in 1918. The dredges of the Yukon and Kuskokwim districts produced gold worth $910,000 from 895,000 cubic yards of gravel, and the value of gold recovered per cubic yard was therefore about $1.02. In 1918 the dredges of the Alaska Yukon districts produced gold worth $881,000 from 1,125,000 cubic yards of gravel, the value of gold recovered per cubic yard being about 78 cents.

Though dredges were built for use in the Alaska Yukon as early as 1898 and at Nome in 1900, this method of placer mining did not reach a profitable stage until 1903, when two small dredges were successfully operated in Seward Peninsula. Dredging began in the Fortymile district in 1907; in the Iditarod, Birch Creek, and Fairbanks districts in 1912; in the Yentna district in 1916; and in the Kuskokwim region in 1918. The new dredge on Candle Creek, in the Kuskokwim region, which was completed and operated for a short period in 1918, did not begin regular operations till 1919. The fact that this dredge and also one of the Fairbanks dredges, which likewise was first operated in 1919, had successful seasons shows that dredging can be profitable even under present adverse conditions. This fact and the successful gold dredging in Seward Peninsula during the last 15 years proves that this type of mining has an important future in Alaska. In nearly every placer-mining district of Alaska there are large areas underlain by auriferous gravels which justify exhaustive prospecting for the purpose of finding dredging ground. The successful use of cold-water thawing in connection with dredging should give a further stimulus to this form of mining. Up to the end of 1919 gold to the value of $20,395,000 had been mined by dredges. The distribution of this output by years is shown in the following table:

Gold produced by dredge mining in Alaska, 1903–1919.

Year.	Number of dredges operated.	Value of gold output.	Gravel handled (cubic yards).	Value of gold recovered per cubic yard.
1903	2	$20,000	....	....
1904	3	25,000	....	....
1905	3	40,000	....	....
1906	3	120,000	....	....
1907	4	250,000	....	....
1908	4	171,000	....	....
1909	14	425,000	....	....
1910	18	800,000	....	....
1911	27	1,500,000	2,500,000	$0.60
1912	38	2,200,000	3,400,000	.65
1913	35	2,200,000	4,100,000	.54
1914	42	2,350,000	4,450,000	.53
1915	35	2,330,000	4,600,000	.51
1916	34	2,679,000	3,900,000	.69
1917	36	2,500,000	3,700,000	.68
1918	28	1,425,000	2,490,000	.57
1919	28	1,360,000	1,760,000	.67
	....	20,395,000	....	....

COPPER.

The copper output of Alaska in 1919 was 47,220,771 pounds, valued at $8,783,063. This is less than the output in 1918, which was 69,224,951 pounds, valued at $17,098,563. During the year, 11 copper mines were operated, compared with 17 in 1918. Of these mines, 3 are in the Ketchikan district, 5 in the Prince William Sound district, and 3 in the Chitina district. The curtailment of copper mining was due to the fall in the price of copper, the uncertainty of the market, and high freight rates. Throughout the war the small operator has been hampered by lack of shipping to transport his ore and of smelters to reduce it, conditions that have blocked the development of a number of properties and discouraged the copper-mining industry. Largely for these reasons there has been relatively little prospecting for copper during the last few years. Should freight rates decrease or the price of copper go up, many small mines would resume operations and the larger low-grade ore bodies would be opened up. Under present industrial conditions there is no likelihood of any improvement during 1920.

Output of Alaska copper mines in 1919, by districts.

District.	Mines operated.	Ore (tons).	Copper.		Gold.		Silver.	
			Quantity (pounds).	Value.	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Ketchikan district	3	8,936	629,100	$117,013	674.11	$13,935	5,261	$5,892
Chitina district [a]	[b] 3	195,631	36,291,390	6,750,198	....	....	408,726	457,773
Prince William Sound	5	288,077	10,300,281	1,915,852	2,412.00	49,860	74,047	82,933
	11	492,644	47,220,771	8,783,063	3,086.11	63,795	488,034	546,598

[a] Also a small amount of placer copper. [b] Kennecott Corp. Ann. Rept. for 1919.

The average copper content of the ores mined in 1919 was 4.8 per cent. The ores also yielded an average of $0.129 in gold and $1.11 in silver to the ton. The average yield for 1918 was 4.8 per cent of copper, $0.149 to the ton in gold, and $0.996 to the ton in silver.

Copper produced in Alaska, 1880–1919.

Year.	Ore mined (tons).	Copper produced.	
		Quantity (pounds).	Value.
1880		3,933	$826
1901		250,000	40,000
1902	[a] 40,000	360,000	41,400
1903		1,200,000	156,000
1904		2,043,586	275,676
1905	52,199	4,805,236	749,617
1906	105,729	5,871,811	1,133,260
1907	98,927	6,308,786	1,261,757
1908	51,509	4,585,362	605,267
1909	34,669	4,124,705	536,211
1910	39,365	4,241,689	538,695
1911	68,975	27,267,878	3,408,485
1912	93,452	29,230,491	4,823,031
1913	135,756	21,659,958	3,357,293
1914	153,605	21,450,628	2,852,934
1915	369,600	86,509,312	15,139,129
1916	617,264	119,854,839	29,484,291
1917	659,957	88,793,400	24,240,598
1918	722,047	69,224,951	17,098,563
1919	492,644	47,220,771	8,783,063
	3,735,698	545,007,336	114,526,096

[a] Estimated.

The copper industry in the three developed copper fields of Alaska is described in the account of mining in those districts given on subsequent pages. In southeastern Alaska the Rush & Brown mine was the largest copper producer. Copper was also produced at the Salt Chuck mine, better known for its output of palladium, and some ore was shipped from the Jumbo mine, at Sulzer. The three large mines, the Bonanza, Jumbo, and Mother Lode, of the Kennecott group, were the only producing mines of the Chitina district in 1919, though some development work was done on other properties. Some placer copper was also recovered incidental to gold-placer mining in the Nizina district.

On Prince William Sound the Beatson-Bonanza and Ellamar copper mines were the only properties worked systematically throughout the year. Some ore was, however, also produced incidental to development work at the Fidalgo or Schlosser mine of the Alaska Mines Corporation, at the Fidalgo or Mackintosh mine of the Fidalgo Mining Co., and at the mine of the Ladysmith Smelting Corporation, on Latouche Island.

Most of the prospecting for copper in 1919 was done in the Susitna basin, tributary to the Alaska Railroad. A number of copper lodes of some promise have been found in this region, but they have not been sufficiently developed to prove their value.

LEAD.

The lead produced in Alaska in 1919 is estimated at 687 tons, valued at $72,822, compared with 564 tons, valued at $80,088, in 1918. The output of lead in 1919 was derived wholly from the concentrates of the gold mines at Juneau.

During 1919 development work was done on galena ores in southeastern Alaska, in the Seward Peninsula, in the Yukon Basin, and probably in other regions. In the course of this work some ore was produced, but so far as known no ore was shipped. The information at hand indicates that the most promising discovery of silver-bearing galena was that made in the Kantishna district. The following table shows the production of lead in Alaska, so far as it can be determined from available data:

Lead produced in Alaska, 1892–1919.

Year.	Quantity (tons).	Value.	Year.	Quantity (tons).	Value.
1892	30	$2,400	1907	30	$3,180
1893	40	3,040	1908	40	3,360
1894	35	2,310	1909	69	5,934
1895	20	1,320	1910	75	6,600
1896	30	1,800	1911	51	4,590
1897	30	2,160	1912	45	4,050
1898	30	2,240	1913	6	528
1899	35	3,150	1914	28	1,344
1900	40	3,440	1915	437	41,118
1901	40	3,440	1916	820	113,160
1902	30	2,460	1917	852	146,584
1903	30	2,520	1918	564	80,088
1904	30	2,580	1919	687	72,822
1905	30	2,620			
1906	30	3,420		4,184	522,258

TIN.

The tin mines of Alaska produced 86 tons of ore containing 112,000 pounds of tin, valued at $73,400 in 1919, compared with 104½ tons of ore containing 136,000 pounds of tin, valued at $118,000, in 1918. The following table shows the production of tin in Alaska since mining began, in 1902:

Tin produced in Alaska, 1902–1919.

Year.	Quantity (tons).		Value.	Year.	Quantity (tons).		Value.
	Ore.	Metal.			Ore.	Metal.	
1902	25	15	$8,000	1912	194	130	$119,600
1903	41	25	14,000	1913	98	50	44,103
1904	23	14	8,000	1914	157.5	104	66,560
1905	10	6	4,000	1915	167	102	73,846
1906	57	34	38,640	1916	232	139	121,000
1907	37.5	22	16,752	1917	171	100	123,300
1908	42.5	25	15,180	1918	104.5	68	118,000
1909	19	11	7,638	1919	86	56	73,400
1910	16.5	10	8,335				
1911	92.5	61	52,798		1,574.0	972	918,152

The York district, of Seward Peninsula, continues to be the center of the tin-mining industry of Alaska. Two dredges and one small open-cut mine were operated in 1919. The dredge of the American Tin Mining Co., on Buck Creek, and of the York Tin Dredging Co., on Grouse Creek, were both in operation. Three men were engaged in shoveling into sluice boxes on Buck Creek above the dredge. A total of 25 men were engaged in tin mining and produced about 56 tons of concentrates, estimated to contain about 76,000 pounds of metallic tin, valued at $49,810. In addition to the tin recovered in the York region a few hundred pounds of tin concentrates were saved in connection with gold mining on Humboldt Creek, a tributary of Goodhope River. These concentrates were not shipped in 1919.

Developments were also continued at the Lost River tin-lode mine, in the York district, where about 12 men worked during the winter of 1918–19 and about 25 men during the summer of 1919. The winter work consisted mainly of retimbering, enlargement of drifts and shafts, and deepening of shafts. A number of buildings were erected, and a compressor plant was installed to furnish air for drills and for ventilation. A large warehouse was also built on the beach at the mouth of the river. A shipment of mining machinery and supplies for this property was landed at the mouth of Lost River in October, 1919.

In the Hot Springs district tin ore was produced from the gold placers in about the same quantity as in recent years. The tin output of the Hot Springs district in 1919 is estimated about 30 tons of concentrates containing about 36,000 pounds of metallic tin, valued at $23,590.

PLATINUM METALS.

The output of platinum, palladium, and other metals of the platinum group in Alaska in 1919 is estimated at 569.52 fine ounces, valued at $73,663, compared with 284 fine ounces, valued at $36,600, in 1918. The larger part of the output in 1919, as in 1918, was derived from the copper-palladium ore of the Salt Chuck mine, in the Ketchikan district, which was operated on a larger scale than before.

Platinum was recovered from the gold placers of Dime, Bear, and Sweepstakes creeks, in the Koyuk or Dime Creek district, Seward Peninsula. The production reported from these creeks in 1919 is only about half as large as in 1918, but the returns for 1919 may not be complete. Platinum was recovered from the gold placers of Slate Creek, in the Chistochina (Copper River) district, in about the same quantity as in 1918. Some platinum may have been saved on Boob Creek, in the Tolstoi (Yukon) district, in 1919, as in previous years, but no returns have been received. The total production of

platinum metals in Alaska since they were first saved in 1916 is shown below.

Platinum metals produced in Alaska, 1916–1919.

Year.	Quantity.		Value.
	Crude ounces.	Fine ounces.	
1916	12.0	8.33	$700
1917	81.2	53.40	5,500
1918	301.0	284.00	36,600
1919	579.3	569.52	73,663
	973.5	915.25	116,463

COAL.

The output of coal in Alaska in 1919 was 60,674 tons, valued at $343,547, compared with 75,606 tons, valued at $411,850, in 1918. This output was about 20 per cent less than that in 1918 but was greater than that in any previous year. The most important features of the Alaska coal-mining industry in 1919 are the continuation of systematic mining in the Matanuska field by the Alaska Engineering Commission, the systematic prospecting of a lease held in the Bering River field, and the beginning of the mining of the Nenana lignitic coal. The larger part of the output in 1918 came from the Matanuska field, which yielded 44,553 tons. The remainder came from eight small mines in different parts of the Territory. All these mines, except those in the Matanuska and Bering River fields, produced coal for local use under free-use permits. About 10 mines were operated, employing about 166 men for an average period of 280 days.

In the Matanuska field mining and underground exploration were carried on throughout the year at the Eska and Chickaloon mines by the Alaska Engineering Commission and 44,553 tons of coal was mined, compared with 63,092 tons in 1918. The production of coal from these mines was advisedly limited to the needs of the commission and near-by localities. At the Eska mine, where the coal is low-grade bituminous, about 150,000 tons of coal have been blocked out and some evidence has been obtained that there is an additional reserve of about 1,000,000 tons. The coal beds at this mine are not greatly folded, but some large faults have complicated the extraction of the coal. At Chickaloon, where the coal is high-grade bituminous, the beds are much folded and faulted, and the conditions increase greatly the cost of mining. The work of the commission has resulted in blocking out about 100,000 tons of coal at the Chickaloon mine. A more complete account of mining in the Matanuska field is given elsewhere in this volume.

No details are yet available about the developments made on the lease held in the western part of Bering River field, but extensive and systematic underground work has been done, and the results appear to have encouraged the lessees to continue. The coal at this locality is high-grade bituminous. Some developments were also continued in 1919 on a patented claim in the northeastern part of the field, where the coal is semianthracite. A little coal has been mined at this locality and marketed at Cordova. The mine is connected by a railroad with barge navigation on Bering River.

The connecting link of the Alaska Railroad between Fairbanks and the Nenana coal field was completed in 1919, except for a bridge over Tanana River,[1] and the Nenana lignite is therefore now available for use in the Fairbanks district and should stimulate the gold-mining industry. Several thousand tons of lignite were produced at "Mile 363 mine" and at "Mile 387 mine" and other developments in the field are under way.

Small lignitic coal mines were operated in 1919 at a number of widely separated localities in Alaska and their product was consumed locally.

The following table gives the estimated production of coal in Alaska since 1888. The figures for 1888 to 1896 are estimated from the best data available but are only approximate. The figures for 1897 to 1919 are based for the most part on data supplied by operators. Most of the coal mined before 1916 was lignite. A small quantity of bituminous coal was produced from the west end of the Bering River field in 1906. The table does not include 855 tons of coal mined in the Bering River field in 1912 and 1,100 tons mined in the Matanuska field in 1913 for test by the United States Navy.

Coal produced in Alaska, 1888 to 1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1888-1896	6,000	$84,000	1909	2,800	$12,300
1897	2,000	28,000	1910	1,000	15,000
1898	1,000	14,000	1911	900	9,300
1899	1,200	16,800	1912	355	2,840
1900	1,200	16,800	1913	2,300	13,800
1901	1,300	15,600	1914	....	....
1902	2,212	19,048	1915	1,400	3,300
1903	1,447	9,782	1916	13,073	52,317
1904	1,694	7,225	1917	53,955	265,317
1905	3,774	13,250	1918	75,606	411,850
1906	5,541	17,974	1919	60,674	343,547
1907	10,139	53,600			
1908	3,107	14,810		252,677	1,440,460

[1] The temporary bridge over Nenana River has been carried out by a flood.

The following table shows the coal consumption of Alaska, including both local production and imports, since 1899. Most of the coal shipped to Alaska was bituminous, but a little was anthracite:

Coal consumed in Alaska, 1899–1919, in short tons.

Year.	Produced in Alaska, chiefly subbituminous and lignite.	Imported from States, chiefly bituminous from Washington.	Total foreign coal, chiefly bituminous from British Columbia.	Total coal consumed.
1899	1,200	10,000	[a] 50,120	61,320
1900	1,200	15,048	[a] 56,623	72,871
1901	1,300	24,000	[a] 77,674	102,974
1902	2,212	40,000	[a] 68,363	110,575
1903	1,447	64,626	[a] 60,605	126,678
1904	1,694	36,689	[a] 76,815	115,198
1905	3,774	67,713	[a] 72,612	144,099
1906	5,541	69,493	[a] 47,590	122,624
1907	10,139	46,246	[a] 93,262	149,647
1908	3,107	23,893	[a] 86,404	113,404
1909	2,800	33,112	69,046	104,958
1910	1,000	32,098	58,420	91,518
1911	900	32,255	61,845	95,000
1912	355	27,767	68,316	96,438
1913	2,300	69,066	56,430	127,796
1914	....	41,509	46,153	87,662
1915	1,400	46,329	29,457	77,186
1916	13,073	44,934	53,672	111,679
1917	53,955	58,116	56,589	168,660
1918	75,606	51,520	37,986	165,112
1919	60,674	57,166	48,708	166,548
	243,677	891,580	1,276,690	2,411,947

[a] By fiscal year ending June 30.

PETROLEUM.

The petroleum produced in Alaska in 1919, as in previous years, was derived wholly from the single patented claim in the Katalla field. The old wells on this claim and the refinery were operated as usual, and two new productive wells were drilled. The total production in 1919 was considerably larger than in 1918.

The new leasing law, which applies to the oil lands in Alaska, has caused a renewal of interest in those lands which have been withdrawn from entry for nearly 10 years. Indications of petroleum have been found in five districts in Alaska, four of which, the Katalla or Controller Bay district, the Yakataga district, the Iniskin Bay district, and the Cold Bay district, are on the Pacific seaboard; and the fifth, which includes areas near Smith Bay, is on the Arctic coast. The oil fields in Alaska began to attract considerable attention in 1896, when claims were staked under the placer law in the Katalla, Yakataga, and Cook Inlet districts. The first well at Katalla was drilled in 1901, and a well was drilled on Cook Inlet at about the same time. There was much activity in the supposed oil fields of Alaska from 1902 to 1904, when many claims were staked in all the fields on the Pacific coast of Alaska and when most of the wells in the Katalla, Iniskin, and Cold Bay districts were drilled. All oil

lands in Alaska were withdrawn from entry November 3, 1910, but in the meanwhile patent had been granted to one claim of 151 acres in the Katalla field and other claims were pending. Assessment work has been continued on some of the claims staked before the withdrawal, especially in the Katalla field, and applications for patents have been made. Drilling for oil has been done only in the Katalla, Iniskin, and Cold Bay fields. About 40 wells, aggregating about 35,000 feet of drilling, have been sunk in Alaska, of which 31 wells, aggregating 28,431 feet of drilling, are in the Katalla field. Oil has been produced commercially only in the Katalla field, which has yielded since 1904 about 56,000 barrels of crude oil for use locally as fuel and for distillation in a small refinery that has been operated since 1912.

Petroleum products shipped to Alaska from other parts of the United States, 1905–1919, in gallons.[a]

Year.	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
1917	23,971,114	3,256,870	750,238	465,693
1918	24,379,566	1,086,852	382,186	362,413
1919	18,784,013	1,007,073	3,515,746	977,703
	237,949,492	23,605,406	11,807,208	3,600,533

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1918, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIAL, ETC.

Marble was produced from one quarry in southeastern Alaska, but in about the same amount as in recent years. The production of gypsum continued at the mine on Chichagof Island. There was no report in 1919 of the production of bricks, quicklime, graphite, or barite, all of which have been produced in previous years. Some developments were made on a sulphur deposit on Akun Island in the Aleutian chain in 1919, and plans were made for the production of sulphur in 1920.

REVIEW BY DISTRICTS.

The following review summarizes briefly the principal developments in all the districts. Many of the districts were not visited by members of the Geological Survey in 1919 and some operators

failed to make reports, so that the information at hand about mining in some of the districts is incomplete. Therefore the space here devoted to any district is not necessarily a measure of its relative importance. The arrangement of the discussion is geographic, from south to north.

SOUTHEASTERN ALASKA.

The mineral output of southeastern Alaska in 1919 was derived from 7 gold-lode mines, 3 copper mines, several small placer mines, 1 gypsum mine, and 1 marble quarry. The value of the minerals produced increased from $3,825,495 in 1918 to $4,679,632 in 1919. The largest mining operations in 1919, as in previous years, were at the gold mines in the Juneau district and at the Chichagof mine, in the Sitka district. Several discoveries of auriferous lodes in the Sitka district are reported. All the copper produced was mined in the Ketchikan district, the largest operations being at the Rush and Brown mine. Placer mining was limited to the Porcupine district and to small beach operations at Lituya Bay and at Yakataga. A more detailed statement of mining developments in southeastern Alaska is presented in a later section of this report (pp. 105–128).

Mineral production of southeastern Alaska, 1919.

	Ore mined (tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Gold-lode mines	3,253,848	201,937	$4,174,407	107,359	$120,242
Copper mines	8,936	674	13,935	5,261	5,892
Placer mines	....	1,209	25,000	204	229
	....	203,820	4,213,342	112,824	126,363

	Copper.		Lead.		Palladium, marble, gypsum, etc. (value).
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	
Gold-lode mines	....	....	1,373,327	$72,822	....
Copper mines	629,100	$117,013	....	....	....
Placer mines	....	....	....	....	....
	692,100	117,013	1,373,327	72,822	$150,092

COPPER RIVER REGION.

The productive mines of the Copper River region in 1919 included three copper mines and one gold-lode mine in the Chitina Valley and about 21 gold-placer mines in the Nizina, Chistochina, and Nelchina districts. The mineral output of the region included copper, silver, gold, and platinum having a total value of $7,395,669.

The mining developments in the Chitina district are summarized in a later chapter of this volume.

The hydraulic placer mines of Nizina district were worked on a large scale. Gold worth about $120,000 was recovered by seven mines operating in the summer. About 77 men were employed. Some placer copper was also recovered.

The Chistochina placer mines are said to have had a very successful season and to have produced gold worth $60,000 from the summer operations of about 10 mines, employing about 30 men. A small amount of platinum was recovered.

PRINCE WILLIAM SOUND.

The value of the minerals produced on Prince William Sound in 1919 was $2,048,892, compared with $3,990,914 in 1918. This amount is the value of the product at five copper mines and one gold-lode prospect.

By far the larger part of the copper output of Prince William Sound in 1919, as in previous years, came from the Beatson-Bonanza mine. Work was continued at the Ellamar copper mine in 1919 on about the same scale as in the past.

Work was continued during the year at the Girdwood mine, which adjoins the Beatson-Bonanza on the north, and incidentally some copper ore was produced and shipped. This property, now controlled by the Ladysmith Smelting Corporation, is being developed in a large way. Developments were also continued at the Schlosser and McIntosh (Fidalgo) mines, on Fidalgo Bay. Assessment work was also done on a number of other copper properties in Prince William Sound. During 1919 gold mining, except for assessment work, was almost at a standstill in the district.

WILLOW CREEK DISTRICT.

The gold-lode mines of the Willow Creek district report a very successful season. The Gold Bullion, Alaska Free Gold, Mabel, Talkeetna, and War Baby mines were operated, producing an aggregate amount of gold worth $162,944 and silver worth $569 from 6,730 tons of ore. A more complete account of mining in the Willow Creek district is given by Mr. Chapin elsewhere in this volume.

YENTNA DISTRICT.

The Cache Creek placers, in the Yentna district, produced in 1919 gold worth about $95,000 from the operation of 15 mines. About 60 men were employed in productive mining and a few were doing dead work. Mining was curtailed during part of the season by shortage of water, but on the whole the season was favorable.

The dredge on Cache Creek did not operate in 1919 but will resume work in 1920.

UPPER SUSITNA REGION.

A little placer mining was done at several localities in the upper Susitna basin, the largest operations being at Valdez Creek. Prospecting for copper has been continued at several localities with encouraging results, but no large developments have yet been made. In general property owners are awaiting the completion of the railroad before attempting systematic developments. To make the copper deposits of this district accessible wagon roads and trails must also be built.

KENAI PENINSULA.

The value of the mineral output of Kenai Peninsula in 1919, including placer gold, lode gold, a small amount of silver obtained incidentally to the mining of the gold, and some lignite mined at Bluff Point, was about $37,500. Of this amount $22,000 is the value of the gold.

There was very little activity in lode-gold mining, and no extensive developments are reported. Three small gold mines were operated during the summer of 1919, and placer mining was continued on a small scale at several localities in Kenai Peninsula.

MATANUSKA, COOK INLET, AND SUSITNA COAL FIELDS.

The coal mines of the Matanuska field supplied the larger part of the Alaskan coal output in 1918, yielding about 44,553 tons of coal, valued at $267,318. A more complete account of mining in the Matanuska field is given by Mr. Chapin in another part of this volume.

The Bluff Point lignite coal mine, at Kachemak Bay, was operated during the summer of 1919 and supplied a local market on Cook Inlet. Some of this lignite was also sold at Anchorage for domestic use. Some lignitic coal was also produced near Snug Harbor for the use of a near-by cannery. Small lignitic coal mines were also operated at Little Susitna and at Hobbs, on the Alaska Railroad.

SOUTHWESTERN ALASKA.

Some development work was continued in 1919 on the McNeil copper property, near Kamishak Bay. A little beach mining was done in 1919, as in the past, at the north end of Kodiak Island. The most important mining event of the year in southwestern Alaska was the installation of a plant to develop a sulphur deposit on Akun Island in the Aleutian chain.

YUKON BASIN.

GENERAL FEATURES.

In spite of the adverse conditions affecting gold mining the value of the mineral product of the Alaska Yukon in 1919 was $3,049,061,

as compared with $4,390,237 in 1918. The sources of the product in 1919 and the total mineral product since mining began in 1886 are shown in the following tables:

Mineral production of Yukon basin, Alaska, in 1919.

	Placer mines.		Lode mines.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold............fine ounces..	140,771	$2,910,000	2,027	$41,393	142,798	$2,951,393
Silver....................do....	19,461	21,796	378	424	19,839	22,220
Tin (metal)..........pounds..	36,000	23,590	....	....	36,000	23,590
Coal.....................tons..	....	....	....	....	10,639	51,878
		2,955,386		41,817		3,049,081

Total mineral production of the Yukon basin, Alaska, 1886–1919.

	Placer mines.		Lode mines.		All mines.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold............fine ounces..	6,209,350	$128,357,000	59,779	$1,235,230	6,269,129	$129,592,230
Silver....................do....	1,070,542	642,322	18,754	8,922	1,089,296	651,244
Tin (metal)..........pounds..	316,410	158,740	....	....	316,410	158,740
Antimony (crude ore)..tons..	....	....	2,251	218,500	2,251	218,500
Tungsten..........................	....	....	....	107,000	....	107,000
Platinum (crude)....ounces..	45	3,100	....	....	45	3,100
Lead.....................tons..	....	....	10	1,672	10	1,672
Coal......................do....	....	....	....	....	21,599	146,203
		129,161,162		1,571,324		130,878,689

In 1919 the Alaska-Yukon placers produced about $2,910,000 worth of gold; in 1918, $4,261,000. The decrease of output is rather evenly distributed among all the districts, but the Iditarod showed the greatest percentage of loss as compared with the previous year. About 274 placer mines, giving employment to 1,246 men, were operated in the Yukon districts during the summer of 1919, and 76, employing about 255 men, were operated during the previous winter. In 1918, 355 placer mines, employing 1,965 men, were worked in the summer, and 121 mines, employing 490 men, in the winter.

Estimated value of gold produced from principal placers of Yukon basin, 1919.

Fairbanks....................	$730,000	Koyukuk.......................	$110,000
Iditarod........................	725,000	Hot Springs....................	100,000
Tolovana......................	525,000	Marshall........................	100,000
Ruby...........................	165,000	All others.......................	170,000
Innoko and Tolstoi...........	150,000		
Circle..........................	135,000		2,910,000

FAIRBANKS DISTRICT.

The value of the total mineral production of the Fairbanks district in 1919 was $778,087, the value in 1918 was $848,989. In 1919, as in the past, the mineral production of the district was chiefly

placer gold. The value of the placer gold produced in 1919 was $730,000 as compared with $800,000 in 1918. About 53 placer mines, employing 350 men, were operated in the district during the summer of 1919, and 24 mines, employing 86 men, during the previous winter. Of the total mines operated in the summer about half were small, employing only 2 to 4 men each. Eighteen of the summer mines are on Goldstream Creek and its tributaries, and the value of their total output of gold was about $275,000. The largest single operations were those of the dredging company, which employed two gold dredges on Fairbanks Creek. Seven relatively large plants were operated on Cleary Creek, and a few on Dome, Vault, and other streams. About 28 deep placer mines were worked in 1919 by shafts and drifts, and by the use of steam for thawing. Many of these, however, were small, employing only 2 to 4 men. This type of mining is on the wane, owing principally to the high cost of fuel. With the use of Nenana coal, which has now been made available to Fairbanks by the completion of the railroad, it should be revived. The most economical form of mining, however, is mining by dredges and steam scrapers. It is shown elsewhere in this volume (p. 11) that the Fairbanks district contains large reserves of gold placers. It should be noted, however, that it will take some time for the placer miners to adapt their plants, now equipped to burn wood, to the use of the Nenana lignitic coal.

The aggregate value of the mineral output of the Fairbanks district to the close of 1919 was $72,044,767. Much the larger part of this amount represents the value of the placer gold, the production of which is shown by years in the subjoined table. In addition to the actual production of the district, about $1,000,000 worth of gold mined in tributary areas passes through Fairbanks each year.

Placer gold and silver produced in the Fairbanks district, 1903–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903	1,935.00	$40,000	348	$188
1904	29,025.00	600,000	5,225	2,821
1905	290,250.00	6,000,000	52,245	28,212
1906	435,375.00	9,000,000	78,367	42,318
1907	387,000.00	8,000,000	69,660	37,616
1908	445,050.00	9,200,000	79,909	43,151
1909	466,818.75	9,650,000	84,027	45,375
1910	295,087.50	6,100,000	53,116	28,683
1911	217,687.50	4,500,000	52,245	27,690
1912	200,756.25	4,150,000	48,182	29,632
1913	159,637.50	3,300,000	20,274	12,245
1914	120,937.50	2,500,000	29,024	16,050
1915	118,518.75	2,450,000	28,444	14,421
1916	87,075.00	1,800,000	11,058	7,276
1917	63,371.25	1,310,000	8,379	6,904
1918	38,700.00	800,000	5,708	5,708
1919	35,313.75	730,000	55,197	5,820
	3,392,538.75	70,130,000	631,408	354,111

The information available as to the source of the gold by creeks is not very accurate. An attempt has been made in the following table, however, to distribute the total placer-gold production of the Fairbanks district by the creeks on which the mines are located:

Approximate distribution of gold produced in Fairbanks district, 1903–1919.

Cleary Creek and tributaries	$23, 060, 000
Goldstream Creek and tributaries	14, 355, 000
Ester Creek and tributaries	11, 330, 000
Dome Creek and tributaries	8, 080, 000
Fairbanks Creek and tributaries	7, 700, 000
Vault Creek and tributaries	2, 665, 000
Little Eldorado Creek	2, 255, 000
All other creeks	685, 000
	70, 130, 000

The first lode mining was done at Fairbanks in 1910 and, as shown in the subjoined table, the industry reached its maximum output in 1915. Since then the relative decline in the value of gold and the high cost of fuel have discouraged this type of mining. Many small lodes in the Fairbanks district will be developed when industrial conditions improve. The records show that the value of the average recovery per ton from the gold ore that has been milled has been about $35. This shows that only the highest grades of ore could be profitably exploited under existing costs of mining and milling. During 1919 lode mining and prospecting have almost ceased, the only operations being those of a few owners who continued a little development with the plan of blocking out ore to be mined when costs are decreased. Incidental to this, a little ore is recovered and milled. Developments of this type were made at half a dozen quartz properties, including the Smith & McGlone, Bondholder, Saint Paul, Gilmore, and Crites & Feldman. The mining of tungsten and antimony ores has been discontinued, owing to the decrease in the price of those metals after the war.

Lode gold and silver produced in the Fairbanks district, 1910–1919.

Year.	Crude ore (short tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	148	841. 19	$17, 389	106	$57
1911	875	3, 103. 02	64, 145	582	308
1912	4, 708	9, 416. 54	194, 657	1, 578	971
1913	12, 237	16, 904. 98	349, 457	4, 124	2, 491
1914	6, 526	10, 904. 75	225, 421	2, 209	1, 222
1915	5, 845	10, 534. 91	217, 776	1, 796	910
1916	1, 111	1, 904. 81	39, 376	140	92
1917	1, 200	2, 311. 38	47, 781	2, 217	1, 826
1918	1, 035	1, 294. 04	26, 750	616	616
1919	1, 384	2, 026. 57	41, 893	378	424
	35, 069	59, 242. 19	1, 224, 645	13, 746	8, 917

HOT SPRINGS DISTRICT.

There were no important mining advances in the Hot Springs district in 1919. Only 12 mines were operated in the summer and 3 during the winter. The mines on Patterson Creek made the largest gold output; those of American Creek made the second largest output. Incidental to gold mining about 30 tons of concentrates containing about 36,000 pounds of metallic tin, worth $23,590, were recovered from the Hot Springs placers. Since 1910 these mines have produced about 262 tons of stream tin, containing about 312,260 pounds of metallic tin, valued at $155,490.

Placer gold and silver produced in the Hot Springs district, 1902–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1902–3	12,717.79	$262,900	1,818	$964
1904	7,038.56	145,500	1,007	584
1905	5,805.00	120,000	831	507
1906	8,707.50	180,000	1,245	843
1907	8,465.63	175,000	1,210	798
1908	7,256.25	150,000	1,038	550
1909	15,721.88	325,000	2,248	1,169
1910	15,721.88	325,000	2,248	1,169
1911	37,974.37	785,000	5,430	2,932
1912	19,350.00	400,000	3,267	2,009
1913	19,350.00	400,000	3,267	1,973
1914	36,281.25	750,000	6,125	3,387
1915	29,508.75	610,000	4,982	2,526
1916	38,700.00	800,000	6,534	4,299
1917	21,768.75	450,000	3,675	3,028
1918	7,256.25	150,000	1,225	1,225
1919	4,837.50	100,000	817	915
	296,461.36	6,128,400	46,967	28,878

TOLOVANA DISTRICT.

About 18 placer mines were operated in the Tolovana district during the summer of 1919 and 7 during the previous winter. Most of the gold recovered in 1919, as in previous years, was taken from the deep mines of Livengood Creek. The immediately available water supply of the Tolovana district is scant, and except in seasons of unusual rainfall the water is likely to be insufficient to sluice up the dumps on Livengood Creek. Such were the conditions in 1918 and 1919.

Though deep mining has dominated in the Tolovana district in the past, the miners there are giving increasing attention to the shallow placers. During the summer of 1919 the miners of the Tolovana district showed considerable interest in the report that placer gold had been found in the Mike Hess and Beaver Creek basins.

Placer gold and silver produced in the Tolovana district, 1915-1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1915	3,870.00	$80,000	321	$163
1916	33,862.50	700,000	2,813	1,851
1917	55,631.25	1,150,000	8,430	6,946
1918	42,328.12	875,000	4,060	4,060
1919	25,396.88	525,000	2,141	2,454
	161,088.75	3,330,000	17,815	15,474

RAMPART DISTRICT.

In the Rampart district 7 mines, employing 21 men in the summer of 1919, and 2 mines, employing 5 men in the previous winter, were operated. The largest mines were on Hunter Creek, where two small hydraulicking plants were operated. With the rest of Alaska, the Rampart district suffered from the scarcity of labor. Cassiterite is found in the concentrates of ores taken from some of the mines, but none of it is being saved.

Placer gold and silver produced in the Rampart district, 1896-1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1896-1903	29,799.00	$616,000	4,440	$2,664
1904	4,353.75	90,000	649	376
1905	3,870.00	80,000	576	351
1906	5,805.00	120,000	865	588
1907	6,046.87	125,000	901	595
1908	3,628.12	75,000	540	286
1909	4,837.50	100,000	721	375
1910	2,080.12	43,000	310	167
1911	1,548.00	32,000	231	125
1912	1,548.00	32,000	274	169
1913	1,548.00	32,000	274	165
1914	1,451.25	30,000	257	142
1915	1,693.13	35,000	300	152
1916	1,935.00	40,000	343	226
1917	1,596.37	33,000	280	231
1918	1,161.00	24,000	206	206
1919	1,451.25	30,000	90	101
	74,352.36	1,537,000	11,257	6,919

RICHARDSON DISTRICT.[1]

Though the region tributary to the town of Richardson, which is on the Fairbanks-Valdez road, has no large mines, it contains much auriferous gravel, and in the aggregate a considerable number of prospectors there support themselves by placer mining. During the last two years some systematic prospecting, part of it done with the use of a churn drill, has been carried on in this district under the leadership of Frank Lawson. The results have encouraged the con-

[1] Called the Salchaket-Tenderfoot district in previous reports.

tinuation of the work. It is estimated that during 1919 some gold was mined on 11 different claims in this district, employing about 20 men.

Placer gold and silver produced in Richardson district, 1905–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1905	(a)	(a)	(a)	(a)
1906	4,837.50	$100,000	989	$673
1907	18,140.62	375,000	3,707	2,447
1908	18,140.62	375,000	3,707	1,965
1909	7,256.25	150,000	1,483	771
1910	4,837.50	100,000	989	534
1911	4,837.50	100,000	989	524
1912	4,837.50	100,000	989	608
1913	4,837.50	100,000	989	597
1914	4,837.50	100,000	989	547
1915	4,595.62	95,000	939	476
1916	3,870.00	80,000	790	520
1917	1,289.37	25,000	245	202
1918	290.25	6,000	59	59
1919	483.75	10,000	99	111
	83,091.48	1,716,000	16,963	10,034

[a] Prospects.

CHISANA DISTRICT.

The Chisana district, which lies in the headwater region of the Tanana River, is one of the most inaccessible in Alaska. Mining here has been on the wane since 1915, though the gold output in 1919 was somewhat greater than that in 1918. The largest part of the gold produced in 1919 was won by rewashing the old tailings of Bonanza Creek.

Placer gold and silver produced in the Chisana district, 1913–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1913	1,935.00	$40,000	465	$280
1914	12,093.75	250,000	2,910	1,609
1915	7,740.00	160,000	1,862	944
1916	1,935.00	40,000	465	306
1917	1,935.00	40,000	420	346
1918	725.63	15,000	160	160
1919	1,306.12	27,000	314	352
	27,670.50	572,000	6,596	3,997

KANTISHNA DISTRICT.

Placer mining was continued in a small way in the Kantishna district during 1919, about 12 mines having been operated. The most important advances reported were those made in lode mining. In 1918 a galena-bearing vein was discovered on the Alice claim, on the ridge between Friday and Eureka creeks. This was opened

up in 1919 by a shaft about 70 feet deep. The vein was followed by a drift, whose length was not reported. The owner reports that the vein ranges in width from 1 to 2 feet and averages about 18 inches. The galena ore contains a high percentage of silver and some gold and copper. The vein traverses schist bedrock and has a calcite gangue. A number of galena and gold prospects in this district have been described by Capps,[3] and development work appears to have been done on some of them in 1919.

The Kantishna district is now difficult of access and is in need of wagon-road connection with the Alaska Railroad. At present supplies for the district are taken up Kantishna and Bearpaw rivers in small launches to the settlement of Diamond. Thence they are sledded to the mines in winter. Several hundred tons of silver ore is said to have been sledded to Bearpaw River from the Alice claim during the winter of 1919, at a cost, including sacking, of $35 a ton. On top of this comes an additional cost of $60 a ton for freight to the States. To meet these high freight charges the ore shipped was carefully picked with the hope that its average value would exceed $150 a ton.

Placer gold and silver produced in the Kantishna district, 1903–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903–1906	8,465.62	$175,000	1,325	$795
1907	725.62	15,000	114	75
1908	725.62	15,000	114	60
1909	241.87	5,000	38	20
1910	483.75	10,000	76	41
1911	1,451.25	30,000	227	120
1912	1,451.25	30,000	227	140
1913	1,451.25	30,000	227	137
1914	967.50	20,000	152	84
1915	967.50	20,000	152	77
1916	1,451.25	30,000	227	149
1917	725.63	15,000	120	99
1918	1,451.25	30,000	227	227
1919	725.63	15,000	114	128
	21,284.99	440,000	3,340	2,152

BONNIFIELD DISTRICT.

In the Bonnifield placer district mining was continued in a small way by six operators. The district contains great bodies of auriferous gravel that carry too low a content of gold to warrant their development except in a large way. When the industrial conditions improve an increase in placer mining may be expected.

[3] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 95–106, 1919.

Placer gold and silver produced in the Bonnifield district, 1903–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903–1906	1,451.25	$30,000	227	$136
1907	241.87	5,000	38	25
1908	241.87	5,000	38	20
1909	2,418.75	50,000	379	197
1910	483.75	10,000	76	41
1911	967.50	20,000	152	81
1912	967.50	20,000	152	93
1913	967.50	20,000	152	92
1914	1,451.25	30,000	227	126
1915	967.50	20,000	152	77
1916	483.75	10,000	76	50
1917	580.50	12,000	98	81
1918	580.50	12,000	91	91
1919	483.75	10,000	75	84
	12,287.24	254,000	1,933	1,194

NENANA COAL FIELD.[4]

The completion of the Alaska Railroad from Fairbanks to the Nenana coal field, except for a bridge at Tanana River, stimulated mining. The Lynn mine was first opened up at Mile 387 on a bed of lignite 4 to 4½ feet thick. This coal proved to be of inferior quality, and work was abandoned after 2,000 tons had been mined.

A lignite of much better grade was found at the Burns mine, Mile 362, where three beds have been developed by entries aggregating 1,000 feet in length. These beds have been traced on the surface for about 2,000 feet. They are somewhat faulted but not enough to affect seriously the cost of mining. About 7,300 tons of coal were taken from this mine in 1919. This coal was used by the Alaska Engineering Commission and by the town of Nenana. The Bureau of Mines has issued the following statement[5] on the steaming value of the Nenana coal:

The Fairbanks station of the Bureau of Mines has recently completed two series of tests designed to determine, first, the comparative steaming value of Alaska lignite and spruce wood, and, second, the resistance of lignite to weathering when stored in piles in the open. The tests were made under the direction of John A. Davis, superintendent of the station, who was assisted by Paul Hopkins and John Gross. These investigations are of special interest to Alaska, since much has been written about the large lignite fields of the Nenana district and their possible value as a fuel supply.

The steaming tests were run to determine the relative value of lignite and spruce wood in the small boilers commonly used in the mining camps of Alaska. Spruce wood has been used for steaming purposes almost exclusively in the past, but the price has risen from $7 to $20 per cord in the last 15 years and other sources of fuel are sought. The lignite used in the tests was not of the highest quality, since it was obtained near the surface. Both the wood and the lignite were carefully weighed, sampled, and analyzed, so that the results of the tests could be accurately compared.

[4] The Nenana coal field lies within the Bonnifield placer district.

[5] Bur. Mines Monthly Rept. nvestigations, February, 1920.

The boiler used was one of a battery of two horizontal water-tube boilers, each rated at 125 brake-horsepower. Two grades of lignite, one from the Lynn mine and one from the Burns mine, and one grade of wood were tested.

The results showed that, under the conditions of these tests, when compared pound for pound the value of spruce wood lay between the values of the two samples of lignite. The relative water evaporations per pound of fuel were: Lynn lignite, 3,06; Burns lignite, 3.99; spruce wood, 3.68 per pound. However, in comparing a cord of wood with a ton of lignite, it was shown that a cord of wood is equivalent to more than a ton of lignite from either mine.

In the weathering tests several hundred pounds of Nenana lignite were used. It was first carefully sampled for analysis and then sized through a series of rings from three-eighths to 2 inches in diameter; 80 per cent of the sample was retained on a 1-inch ring. The lignite was then spread in shallow trays and placed on the roof of the station, where it was allowed to remain, fully exposed to the weather, for 14 months. At the end of a week it was noticeably weathered on the surface, and at the end of a month it had broken up into small pieces.

At the end of the test period it was found that the surface portion, immediately exposed to the atmosphere, was entirely disintegrated, while that farthest from the surface was only partly disintegrated, although very fragile. Over 50 per cent would then pass through a three-eighth inch ring and 85 per cent passed a three-fourth inch ring. The average loss in weight through weathering was 6.08 per cent (mostly moisture). The weathering at the end of 14 months, however, seemed only slightly more than that at the end of 1 month. In large piles only the surface, to a depth of 4 to 6 inches, would weather badly, and the material beneath would be so protected as to suffer little change. These tests show that the behavior of these lignites is substantially the same as that of North Dakota lignite.

Early in 1920 permits were granted to mine coal at two other places in the Nenana field. One is on the west side of Nenana River, on Lignite Creek; the other on the east side, close to the canyon. Development work on these claims is under way.

CIRCLE DISTRICT.

The output of the gold placers of the Circle district in 1919 was the smallest since 1894. About 18 mines, employing about 30 men, were operated in the winter of 1918–19, and 26 mines and one dredge, employing 77 men, in the summer of 1919. The largest operations included the dredge on Mastodon Creek and hydraulic mines on Mastodon and Eagle creeks. The smallness of the output was due to shortage of water and late thawing, to curtailment of operations because of high costs, and to the deaths of several large operators of the district in the wreck of the *Sophia*. No new discoveries were reported and no new projects were undertaken.

Placer gold and silver produced in the Circle district, 1894–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1894	483.75	$10,000	123	$77
1895	7,256.25	150,000	1,886	1,226
1896	33,862.50	700,000	8,794	6,080
1897	24,187.50	500,000	6,289	3,773
1898	19,350.00	400,000	5,031	2,968
1899	12,093.75	250,000	3,144	1,886
1900	12,093.75	250,000	3,144	1,886
1901	9,675.00	200,000	2,512	1,507
1902	9,675.00	200,000	2,512	1,331
1903	9,675.00	200,000	3,144	1,698
1904	9,675.00	200,000	3,144	1,823
1905	9,675.00	200,000	3,144	1,918
1906	14,512.50	300,000	3,773	2,565
1907	9,675.00	200,000	3,144	2,075
1908	8,465.63	175,000	2,212	1,166
1909	10,884.37	225,000	2,830	1,472
1910	10,884.37	225,000	2,830	1,528
1911	16,931.25	350,000	4,402	2,333
1912	15,721.87	325,000	2,439	1,500
1913	8,465.63	175,000	1,314	794
1914	10,884.37	225,000	1,689	934
1915	11,126.25	230,000	1,727	875
1916	14,512.50	300,000	2,252	1,482
1917	9,675.00	200,000	1,561	1,285
1918	8,465.63	175,000	1,798	1,798
1919	6,530.63	135,000	1,260	1,411
	314,437.50	6,500,000	76,098	47,391

FORTYMILE DISTRICT.

Placer mining in the Fortymile district, as in all the other isolated districts of Alaska, declined in 1919, when the gold output was smaller than in any previous year. Some productive work was done at about 20 mines, but most of these were small. The largest output was made from Jack Wade Creek and Walkers Fork. A hydraulic plant on Dome Creek that had been in process of installation since 1917 was completed but was operated only a short time. This plant is intended to exploit bench gravels. Another company has been exploring the placers of Dennison Fork and the adjacent region with a view of installing large plants. The Fortymile district contains much auriferous gravel whose gold content is great enough to justify mining when costs are reduced. A good wagon road into the district from Yukon River is very much needed.

Placer gold and silver produced in the Fortymile district, 1886–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1886–1903	193,500.00	$4,000,000	30,553	$22,915
1904	14,851.12	307,000	2,345	1,360
1905	12,384.00	256,000	1,955	1,193
1906	9,868.50	204,000	1,558	1,059
1907	6,772.50	140,000	1,069	706
1908	6,772.50	140,000	1,069	567
1909	10,884.37	225,000	1,719	894
1910	9,675.00	200,000	1,528	825
1911	9,575.00	200,000	1,528	810
1912	10,303.87	213,000	1,627	1,000
1913	4,837.50	100,000	764	461
1914	2,418.75	50,000	382	211
1915	2,418.75	50,000	382	194
1916	2,418.75	50,000	382	251
1917	3,870.00	80,000	624	513
1918	3,628.12	75,000	573	573
1919	1,963.37	41,000	313	350
	306,262.10	6,331,000	48,371	33,882

EAGLE DISTRICT.

The output of placer gold in the Eagle district in 1919 was about the same as in 1918. Most of it was mined on tributaries of Seventymile River and American Creek, where 14 mines were operated, employing 30 men. No new developments or discoveries were reported.

Placer gold and silver produced in the Eagle and Seventymile districts, 1908–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1908	483.75	$10,000	76	$40
1909	1,209.37	25,000	191	99
1910	483.75	10,000	76	41
1911	580.50	12,000	92	49
1912	967.50	20,000	164	100
1913	2,418.75	50,000	382	231
1914	2,418.75	50,000	382	211
1915	1,935.00	40,000	305	155
1916	822.37	17,000	130	86
1917	628.88	13,000	96	75
1918	1,209.37	25,000	191	191
1919	969.50	20,000	152	170
	14,127.49	292,000	2,237	1,448

CHANDALAR DISTRICT.

Little information has been received concerning mining in the Chandalar district. The placers were apparently worked on about the customary scale, two summer mines and one winter mine employing eight and five men, respectively.

Placer gold and silver produced in the Chandalar district, 1906–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1906–1912	2,902.50	$60,000	416	$241
1913	266.06	5,500	38	23
1914	241.87	5,000	35	19
1915	241.87	5,000	35	18
1916	435.37	9,000	62	41
1917	725.63	15,000	104	86
1918	628.88	13,000	96	96
1919	453.75	10,000	79	88
	5,895.93	122,500	865	612

KOYUKUK DISTRICT.

In the Koyukuk district, in spite of its extreme isolation, considerable placer mining was done in 1919. It is estimated that 15 mines, employing 60 men, were operated during the summer of 1919, and 3 mines, employing 10 men, during the previous winter. The largest operations were those on Nolan Creek. Gold placers were discovered on Hogatza River, in the Koyukuk district, in 1919, but the developments are not yet sufficient to determine their value. Placers are also reported to have been discovered in the basin of Birch Creek, a tributary of Wild River, and also in the Koyukuk district, though the reports have not been verified. These placers are in inaccessible regions and would have to be very rich to justify their development under present conditions. The reports, however, indicate that not all the Alaska prospectors have become discouraged.

Placer gold and silver produced in the Koyukuk district, 1900–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1900–1909	106,454.02	$2,200,600	15,242	$8,993
1910	7,740.00	160,000	1,108	598
1911	6,772.50	140,000	970	514
1912	9,675.00	200,000	1,385	852
1913	19,350.00	400,000	2,770	1,673
1914	12,577.50	260,000	1,800	995
1915	13,303.12	275,000	1,902	964
1916	14,996.25	310,000	2,147	1,413
1917	12,093.75	250,000	1,700	1,401
1918	7,256.25	150,000	860	860
1919	5,321.25	110,000	760	851
	215,539.64	4,455,600	30,644	19,114

INDIAN RIVER AND GOLD HILL DISTRICTS.

Mining was continued in a very small way in the Indian River and Gold Hill districts of the Middle Yukon Valley during 1919. It is estimated that only five placer mines were operated.

Placer gold and silver produced in the Indian River and Gold Hill districts, 1911–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1911	483.75	$10,000	69	$37
1912	1,185.19	24,500	170	106
1913	1,548.00	32,000	221	133
1914	1,209.37	25,000	173	96
1915	725.63	15,000	104	53
1916	483.75	10,000	69	45
1917	241.88	5,000	27	22
1918	193.50	4,000	29	29
1919	338.62	7,000	52	58
	6,409.69	132,500	914	578

RUBY DISTRICT.

Placer mining in the Ruby district declined greatly in 1919 as compared with previous years. About 22 mines, employing 80 men, were operated during the summer of 1919, and only 2 during the previous winter. A new gold-bearing channel was discovered on Flat Creek and was profitably developed. Some new gold discoveries were also made on Poorman Creek. There were also large mining operations on Greenstone Creek.

Placer gold and silver produced in the Ruby district, 1907–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1907–8	48.38	$1,000	7	$4
1909				
1910				
1911				
1912	8,465.63	175,000	1,157	712
1913	37,974.37	785,000	5,188	3,134
1914	48,375.00	1,000,000	6,609	3,655
1915	33,862.50	700,000	4,626	2,345
1916	41,118.75	850,000	5,618	3,697
1917	42,811.88	885,000	6,073	5,046
1918	19,350.00	400,000	3,000	3,000
1919	7,981.88	165,000	1,255	1,406
	239,988.39	4,961,000	33,533	22,999

INNOKO AND TOLSTOI DISTRICTS.

Placer mining was continued in the Innoko and Tolstoi districts on about the same scale as during previous years. A total of 17

mines, employing 68 men, were operated in the summer of 1919, and 12, employing 15 men, in the previous winter. The largest plants were on Ophir and Gaines creeks. Considerable prospecting of auriferous lodes was done during the year. Some ore was recovered with the view of making shipments for mill tests.

Placer gold and silver produced in the Innoko and Tolstoi districts, 1907–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1907	628.87	$13,000	67	$44
1908	3,483.00	72,000	370	196
1909	16,447.50	340,000	1,746	908
1910	15,721.87	325,000	1,669	901
1911	12,093.75	250,000	1,284	681
1912	12,093.75	250,000	1,284	681
1913	13,545.00	280,000	1,438	869
1914	9,675.00	200,000	1,027	568
1915	9,191.25	190,000	976	495
1916	10,642.50	220,000	1,130	744
1917	8,465.63	175,000	1,113	917
1918	5,805.00	120,000	608	608
1919	6,772.50	140,000	717	803
	124,565.62	2,575,000	13,429	8,415

IDITAROD DISTRICT.

The operation of two gold dredges in the Iditarod district was continued in 1919, but as compared with 1918 other forms of placer mining decreased. It is estimated that a total of 12 mines, employing 70 men, were operated in the summer of 1919, and 3 mines, employing 20 men, in the previous winter.

Placer gold and silver produced in the Iditarod district, 1910–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	24,187.50	$500,000	4,254	$2,297
1911	120,937.50	2,500,000	21,270	11,273
1912	169,312.50	3,500,000	29,778	18,313
1913	89,977.50	1,860,000	9,551	5,769
1914	99,652.50	2,060,000	10,578	5,849
1915	99,168.75	2,050,000	10,526	5,337
1916	94,331.25	1,950,000	10,013	6,589
1917	72,562.50	1,500,000	11,050	9,105
1918	59,985.00	1,240,000	9,000	9,000
1919	35,071.88	725,000	5,300	5,937
	865,186.88	17,885,000	121,320	79,469

MARSHALL DISTRICT.

Productive mining in the Marshall district was nearly all confined to Willow Creek. About eight mines were operated in the district during the summer of 1919, employing some 56 men.

Placer gold and silver produced in the Marshall district, 1914–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1914	725.62	$15,000	94	$52
1915	1,209.37	25,000	156	79
1916	13,061.25	270,000	1,686	1,109
1917	20,559.37	425,000	3,300	2,719
1918	7,256.25	150,000	940	940
1919	4,837.50	100,000	624	699
	47,649.36	985,000	6,800	5,598

KUSKOKWIM REGION.

Mining interest in the Kuskokwim Valley during 1919 centered in the McGrath (Mount McKinley) district. Here the principal events were the successful operation during the entire season of the gold dredge installed on Candle Creek in 1918, and the discovery and development of a number of lodes carrying gold, silver, and some copper. The most promising of the lodes discovered are on Nixon Fork, 10 to 20 miles from Kuskokwim River. These lodes appear to lie in a zone of mineralization along a contact of limestone and intrusive granite. The most important developments are on the Crystal lode, said to be 3 to 5 feet in width and to carry considerable gold and some silver and copper. In the fall of 1919 preparations were made to open up this lode and make a shipment in the summer of 1920 of a thousand tons of ore for a smelter test. Other promising auriferous lodes have been found and prospected. A specimen sent to the Geological Survey by Dr. W. F. Green from the Whelen claim, contained copper and a little nickel. Another specimen, from Roundabout Mountain, also sent by Dr. Green, contained pyrite and chalcopyrite and a trace of nickel. The evidence in hand indicates that a part of this district is well mineralized, and this augurs well for the finding of commercial ore bodies.

Mining was continued in the Aniak-Tuluksak district, including Georgetown, in the Kuskokwim district during 1919, but on a reduced scale as compared with previous years. Some dredging ground on Marvel Creek, in this district, was prospected. Placer mining in the Goodnews Bay district, which is described elsewhere in this volume, was also continued on a reduced scale.

The value of the total gold produced in the Kuskokwim Valley in 1919 was about $350,000. The value in 1918 was $100,000. The substantial increase in 1919 is to be credited to the McGrath district. In 1919 about 20 placer mines, employing about 100 men, were in operation in all the Kuskokwim districts. Work was continued at the Parks quicksilver mine on the lower Kuskokwim. A retorting

plant was shipped in during the summer of 1919 and installed about the end of the year. About 30 men were employed at this mine.

The Kuskokwim Valley, because of lack of steamers, is rather difficult of access. Small ocean vessels can ascend the Kuskokwim as far as Bethel, and the river is navigable by smaller craft for some 600 miles above that place. As mining increases better service will no doubt be established, but the only communication with Seattle in 1919 was afforded by small gas boats and schooners. Some five boats were used on this run, the largest of which had a capacity of about 1,000 tons. The passage from Seattle takes about 30 days. Passenger rates from Seattle to Bethel in 1920 were $125 and freight rates were about $30 a ton. Freight is carried from Bethel up the Kuskokwim to McGrath and other places by a river steamer. This boat makes two or three trips a season and can carry about 300 tons of freight. The up-river journey from Bethel to McGrath takes about 10 days. In 1919 about 3,000 tons of freight was carried to Bethel from Seattle, of which about 800 tons was sent up the river as far as McGrath. McGrath can be reached by overland horse trail from Iditarod and Ruby. The lower Kuskokwim Valley can be reached by way of the mail route that crosses the Portage trail from lower Yukon River.

SEWARD PENINSULA.

The value of the mineral output of Seward Peninsula in 1919 was about $1,423,449, compared with $1,195,172 in 1918. Of the output in 1919, $1,360,000 represents the value of the placer gold and $63,449 the value of the miscellaneous products, including tin, lode gold, silver, and platinum. The value of the placer gold produced in 1918 was $1,108,000, so that there was a substantial increase.

In all 24 gold dredges were operated in Seward Peninsula during 1919, distributed as follows: Nine in the Nome district, eight in the Council district, four in the Solomon district, and one each in the Kougarok, Fairhaven, and Port Clarence districts. Three dredges used the so-called cold-water method of thawing the gravels. In addition to the dredges, about 75 open-cut mines and 13 deep placer mines were operated on Seward Peninsula in 1919. About 555 men were employed in placer mining and about 60 of these were employed in deep mining during the winter. Some 32 ounces of platinum was won from the gold placers of the Dime Creek region, in the southeastern part of Seward Peninsula. There were some small developments on auriferous quartz and galena deposits of Seward Peninsula in 1919.

The York district, of Seward Peninsula, continues to be the center of the tin-mining industry of Alaska. Here two dredges and one small open-cut mine were operated in 1919 on placer tin, employing some 25 men, and about 56 tons of stream tin was recovered by these

operations. (See p. 229.) Developments were also continued at the Lost River tin-lode mine, in the same district, where about 25 men were employed. A more detailed statement of the mining developments in the Seward Peninsula is given in another part of this report.

KOBUK RIVER.

About $25,000 worth of gold was taken from the gold placers of the Kobuk district in 1919, as compared with $15,000 in 1918. Seventeen mines were operated, employing about 40 men. Most of the gold was taken from Klery and Dahl creeks. It is reported that James Cross and Harry Brown discovered gold in the Ambler Valley of the Kobuk region. The gold is said to be bright and rather coarse and to include flat nuggets. It is reported that at least $1,000 was taken out during the summer of 1919.

ADMINISTRATIVE REPORT.

By ALFRED H. BROOKS and GEORGE C. MARTIN.

INTRODUCTION.

During 1919 twelve parties were engaged in surveys and investigations in Alaska. The length of the field season ranged from 1 to 12 months, being determined by the character of the work and by the climatic conditions prevailing in different parts of the Territory. The parties included 8 geologists, 3 topographers, 1 engineer, and 12 packers, cooks, and other auxiliaries. Eight of the parties were engaged in geologic surveys, three in topographic surveys, and one in stream gaging. The areas covered by reconnaissance geologic surveys on a scale of 1:250,000 (4 miles to an inch) amount to 3,300 square miles. Much of the time of the geologists was devoted to the investigation of special problems relating to the occurrence of minerals, the results of which can not be expressed in terms of area. About 2,300 square miles was covered by reconnaissance topographic surveys on a scale of 1:250,000 (4 miles to an inch). Stream gaging was continued in southeastern Alaska, in cooperation with the Forest Service.

Of the parties whose work may be classified geographically, two parties worked in southeastern Alaska, three in the Cook Inlet-Susitna region, and one each in the Yukon, Copper River, and Kuskokwim regions and in Seward Peninsula.

The funds available for field and office work relating to the field season of 1919 included an appropriation of $75,000 for the fiscal year ending June 30, 1920, and the unexpended balance of the appropriation for the year ending June 30, 1919, of which about $16,700 was used in equipping parties for the season's field work. The following tables show the allotments, for both field and office work, of the total funds classified by regions, by kinds of surveys, and by kinds of expenditures. In the first table the general office expenses are apportioned to the several allotments, account being taken of variations in character of work. The results are expressed in round numbers. Salaries of the permanent staff, other fixed charges, and the total allotments for the work of the office at Anchorage are included up to the end of the fiscal year 1920, but expenses other than these include only the cost of field and office work during 1919. The "general investigations" comprise among other things the cost of col-

lecting mineral statistics, and of office work relating to the field investigations of previous seasons. A balance of about $10,400 from the appropriation for the year ending June 30, 1920, is available for equipping the field parties in 1920.

Approximate general distribution of appropriations for investigations in Alaska, field season of 1919.

	1918-19	1920
Southeastern Alaska	$500	$13,200
Copper River region		1,800
Cook Inlet and Susitna basin	13,200	22,900
Yukon basin		2,300
Kuskokwim region	3,000	8,700
General investigations		15,700
To be allotted to field work, 1920		10,400
	16,700	75,000

Approximate allotments to different kinds of surveys and investigations, field season of 1919.

	1918-19	1920
Reconnaissance geologic surveys	$8,600	$17,600
Special geologic investigations		9,900
Reconnaissance topographic surveys	8,100	9,800
Investigation of water resources		4,200
Collection of mineral statistics		1,900
Miscellaneous, including administration, inspection, clerical salaries, office supplies and equipment, and map compilation		21,200
To be allotted to field work, 1920		10,400
	16,700	75,000

Allotments for salaries and field expenses, field season of 1919.

	1918-19	1920
Scientific and technical salaries		$33,458
Field expenses	$16,700	15,421
Clerical and administrative salaries and miscellaneous expenses		15,721
To be allotted to field work, 1920		10,400
	16,700	75,000

The following table exhibits the progress of investigations in Alaska and the annual grant of funds since systematic surveys were begun in 1898. It should be noted that a varying amount is spent each year on special investigations that yield results which can not be expressed in terms of area.

Progress of surveys in Alaska, 1898–1919.

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[a]					Water resources investigations.	
		Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000).	Detailed (scale 1:62,500).	Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000; 200-foot contours).	Detailed (scale 1:62,500; 25, 50, or 100 foot contours).	Lines of levels.	Bench marks set.	Gaging stations maintained part of year.	Stream-volume measurements.
		Sq. m.	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Miles.*			
1898	$46,189	9,500			12,840	2,070					
1899	25,000	6,000			8,690						
1900	60,000	3,300	6,700		630	11,150					
1901	60,000	6,200	5,800		10,200	5,450					
1902	60,000	6,950	10,050		8,330	11,970	96				
1903	60,000	5,000	8,000	96		15,000					
1904	60,000	4,050	3,500		800	6,480	480	86	19		
1905	80,000	4,000	4,100	536		4,880	787	202	28		
1906	80,000	5,000	4,000	421		13,500	40			14	286
1907	80,000	2,600	1,400	442		6,120	501	95	16	48	457
1908	80,000	2,000	2,850	604		3,980	427	76	9	53	556
1909	90,000	6,100	5,500	450	6,190	5,170	444			81	703
1910	90,000		8,635	321		13,815	36			69	429
1911	100,000	8,000	10,550	496		14,460	246			68	300
1912	90,000		2,000	525			298			69	381
1913	100,000	3,500	2,950	180	3,400	2,535	287				
1914	100,000	1,000	7,700	325	600	10,300	10				
1915	100,000		10,700	200		10,400	12	3	2	9	
1916	100,000		5,100	636		9,700	67			20	
1917	100,000		1,750	275		1,050				19	
1918	77,000		3,500			1,200					
1919	75,000		2,700			2,300				19	
		73,200	107,485	5,507	51,680	151,530	3,731	462	74		
Percentage of total area of Alaska		12.48	18.33	0.94	8.81	25.83	0.64				

[a] The Coast and Geodetic and International Boundary surveys and the General Land Office have also made topographic surveys in Alaska. The areas covered by these surveys are of course not included in these totals.

George C. Martin directed the work of the division of Alaskan mineral resources until May 4, when Alfred H. Brooks, having received his discharge from the Army, resumed his former duties. Much of Mr. Brooks's time between May 4 and his departure for Alaska in August was devoted to duties other than those relating to Alaska. Mr. Brooks, in company with Mr. John Hallowell, Assistant to the Secretary of the Interior, sailed from Seattle for Alaska on August 15, and devoted the following six weeks to a study of the region adjacent to the Government railroad, making also brief visits to the Matanuska coal field and the Fairbanks district. He returned from the interior by wagon road to Chitina and thence by railway to Cordova. During this part of the journey a side trip was made to the Kennecott-Bonanza mine.

Of the total of 88 days given to Alaska office work between May 4 and December 31, Mr. Brooks devoted 12 days to critical reading of manuscript, 9 to preparation of the annual press bulletin, 3 to field plans, and 18 days to geologic studies. The rest of the time was devoted to routine and administrative duties. Mr. Martin, in addition to doing a large amount of administrative work, spent much time in preparing this volume and in compiling and coordinating the mineral statistics. He also prepared a summary report on the Alaska oil fields and continued his studies on the Mesozoic geology of Alaska. His field work is referred to below.

Miss Lucy Graves, chief clerk of the division, has assisted the geologist in charge in various phases of administrative duties. She has charge of clerical work and the files and makes administrative examination of all accounts and vouchers. Much of the work of compiling the statistics of the mineral production of Alaska has been done by Mr. T. R. Burch.

GEOGRAPHIC SUMMARY.

SOUTHEASTERN ALASKA.

The investigation of the water resources of southeastern Alaska, begun in 1915 under a cooperative agreement with the Forest Service, was continued throughout 1919. G. H. Canfield, who had charge of this work, maintained automatic gages throughout the year. In addition to these gages, others were installed in cooperation with individuals and corporations. The results are briefly summarized in another part of this report. This work could not have been carried on without the cordial cooperation of the Forest Service, many members of which have given substantial aid. Particular acknowledgment should be made to C. H. Florey, forest supervisor at Ketchikan.

A reconnaissance of the geology and mineral deposits of parts of the Glacier Bay and Lynn Canal regions was made by J. B. Mertie, jr. Field work was begun on July 23 and continued until September 18. An area of about 200 square miles was mapped in reconnaissance. Mr. Mertie also visited the productive mines of the Juneau and Ketchikan districts.

COPPER RIVER REGION.

The completion of the report on the Kotsina-Kuskulana district, which was suspended by the assignment of Mr. Moffit to work for the War Department during the war, required the gathering of a small amount of additional field data in order to bring it up to date. Mr. Moffit spent September in this work.

COOK INLET AND SUSITNA REGIONS.

Because of the importance of the region tributary to the Government railroad and the growing demand for information concerning it, a special effort is being made to complete the mapping of that region. The surveys and investigations in the Cook Inlet and Susitna regions in 1919 included a topographic and geologic reconnaissance survey of areas between Talkeetna River and Broad Pass and in the upper Kantishna region, as well as detailed investigations at the coal mines in the Matanuska Valley.

A party in charge of S. R. Capps, assisted by S. H. Cathcart, made reconnaissance surveys on the scale of 1:180,000 of an area of about 300 square miles in the high mountains on the headwaters of the Kantishna and of the upper tributaries of the Susitna. T. P. Pendleton, attached to this party, made topographic surveys of the same area. The party began field work on the north side of the Alaska Range June 28 and finished August 27, crossing the Alaska Range and returning to the coast by way of Susitna River.

A topographic reconnaissance survey of an area adjacent to the Government railroad between Talkeetna River and Broad Pass was made by J. R. Eakin from June 22 to September 12. An area of about 600 square miles was mapped on a scale of 1 : 180,000. R. M. Overbeck completed geologic surveys of the same area.

YUKON REGION.

The placer mines of the Eagle and Circle districts were visited by G. C. Martin from August 16 to September 13 for the purpose of obtaining information concerning recent mining conditions and developments.

GOODNEWS BAY.

Topographic and geologic reconnaissance surveys of an area in the vicinity of Goodnews Bay and the lower Kuskokwim were made by a party in charge of R. H. Sargent. Mr. Sargent mapped topographically an area of 1,400 square miles on the scale of 1:180,000. G. L. Harrington, who accompanied Mr. Sargent's party, made a reconnaissance geologic map of an area of about 2,000 square miles. Field work began July 4 and ended August 17.

SEWARD PENINSULA.

After the end of his field work in the Kuskokwim region, G. L. Harrington made investigations of general mining developments in Seward Peninsula. He was engaged in this work till October.

ALASKA OFFICE.

The branch office of the Geological Survey at Anchorage, in charge of Theodore Chapin, was maintained throughout the year. The main

purpose in opening this office is to provide the means of close cooperation between the Geological Survey and those in charge of the operation of the Government coal mines in the Matanuska Valley. It is also the purpose of the resident geologist to do everything possible to aid the mining industry in the region tributary to the Government railroad, to keep in close touch with all local developments in mining and prospecting, and to furnish whatever aid may be possible by giving information, advice, and publications to all who are engaged in mining and prospecting.

COLLECTION OF STATISTICS.

The collection of statistics of production of metals in Alaska, begun by the Alaska division in 1905, was continued as usual. Preliminary estimates of mineral production for the previous year were published on January 1.

PUBLICATIONS.

During 1919 the Survey published six bulletins and one professional paper relating to Alaska. In addition, two bulletins were in press and 13 reports, including this volume, were in preparation at the end of the year. Eight topographic maps were published, and nine were in preparation at the end of the year.

REPORTS ISSUED.

Professional Paper 109. The Canning River region, northern Alaska, by E. deK. Leffingwell.

Bulletin 668. The Nelchina-Susitna region, Alaska, by Theodore Chapin.
Bulletin 664. The Nenana coal field, Alaska, by G. C. Martin.
Bulletin 683. The Anvik-Andreafski region, Alaska, by G. L. Harrington.
Bulletin 687. The Katishna region, Alaska, by S. R. Capps.
Bulletin 692. Mineral resources of Alaska, 1917, by G. C. Martin and others.
Bulletin 699. The Porcupine district, Alaska, by H. M. Eakin.

REPORTS IN PRESS.

Bulletin 682. The marble resources of southeastern Alaska, by E. F. Burchard. (Published in November, 1920.)

Bulletin 712. Mineral resources of Alaska, 1918, by G. C. Martin and others. (Published in October, 1920.)

Bulletin 719. Preliminary report on petroleum in Alaska, by G. C. Martin.

REPORTS IN PREPARATION.

Chromite of Kenai Peninsula, Alaska, by A. C. Gill.
The upper Matanuska basin, Alaska, by G. C. Martin.
The Mesozoic stratigraphy of Alaska, by G. C. Martin.
The Kotsina-Kuskulana district, Alaska, by F. H. Moffit.
The lower Kuskokwim region, Alaska, by A. G. Maddren.
The Ruby-Kuskokwim region, Alaska, by J. B. Mertie, jr., and G. L. Harrington.
The Cretaceous and Tertiary floras of Alaska, by Arthur Hollick.
The Juneau district, Alaska, by A. C. Spencer and H. M. Eakin.
The Ketchikan district, Alaska, by Theodore Chapin.

York tin deposits, Alaska, by Edward Steidtmann and S. H. Cathcart.

Geology and mineral resources of region tributary to Alaska Railroad, by S. R. Capps.

TOPOGRAPHIC MAPS ISSUED.

Canning River region, by E. deK. Leffingwell; scale, 1:250,000; sketch contours. (Plate I, Professional Paper 109.)

North Arctic coast, by E. deK. Leffingwell; scale, 1:500,000; no contours. (Plate III, Professional Paper 109.)

Coast line between Challenge Entrance and Thetis Island, by E. deK. Leffingwell; scale, 1:125,000; no fixed contour interval. (Plate IV, Professional Paper 109.)

Coast line between Martin Point and Challenge Entrance, by E. deK. Leffingwell; scale, 1:125,000; no fixed contour interval. (Plate V, Professional Paper 109.)

Nelchina-Susitna region, by J. W. Bagley; scale, 1:250,000; contour interval, 200 feet. (Plate I, Bulletin 668.)

Anvik-Andreafski region, by R. H. Sargent; scale, 1:150,000; contour interval, 100 feet. (Plate I, Bulletin 683.)

Marshall mining district, by R. H. Sargent; scale, 1:125,000; contour interval, 100 feet. (Plate II, Bulletin 683.)

Kantishna region, by C. E. Giffin; scale, 1:250,000; contour interval, 200 feet. (Plate I, Bulletin 687.)

TOPOGRAPHIC MAPS READY FOR ENGRAVING.

Kotsina-Kuskulana district, by D. C. Witherspoon; scale, 1:62,500; contour interval, 100 feet.

Lower Kuskokwim region, by A. G. Maddren; scale, 1:500,000; contour interval, 400 feet.

Ruby district, by C. E. Giffin and R. H. Sargent; scale, 1:250,000; contour interval, 200 feet.

TOPOGRAPHIC MAPS IN PREPARATION.

Innoko-Iditarod region, by R. H. Sargent and C. E. Giffin; scale, 1:250,000; contour interval, 200 feet.

Port Wells region, by J. W. Bagley; scale, 1:250,000; contour interval, 200 feet.

Jack Bay district, by J. W. Bagley; scale, 1:62,500; contour interval, 50 feet.

Fidalgo-Gravina district, by D. C. Witherspoon; scale, 1:250,000; contour interval 200 feet.

Susitna-Chulitna district, by D. C. Witherspoon; scale, 1:250,000; contour interval, 200 feet.

Seward-Fairbanks route; compiled; scale, 1:250,000; contour interval, 200 feet.

LODE MINING IN THE JUNEAU AND KETCHIKAN DISTRICTS.

By J. B. Mertie, Jr.

INTRODUCTION.

During the last few years gold mining has been increasingly difficult to conduct as a profitable enterprise. The advances in cost of labor and commodities of all kinds have worked a special hardship upon the gold-mining industry, for the standard and unchanging value of gold has rendered it impossible to offset the high prices by increasing the market value of the product, as in other industries. Low-grade gold properties that were formerly worked on a small margin of profit by means of large-scale operations are now either scarcely earning their operating expenses, or are being worked at an actual loss for the sake of enabling the operators to hold their organizations together. Properties of somewhat higher grade are likewise adversely affected, for even for them gold mining has become much less profitable. This condition is reflected in southeastern Alaska by a general policy of retrenchment in mining operations on the part of owners and operators of gold mines. Moreover, present economic conditions have had a very hurtful influence, both economic and psychologic, upon the development of new gold mines.

In the Juneau gold belt the Alaska-Gastineau, Alaska-Juneau, and Treadwell properties were operated in 1919, and prospecting and development work were carried on at the Jualin mine, Berners Bay; at the property of the Admiralty-Alaska Gold Mining Co., at Funter Bay; at the Red Wing group of claims, at the head of Windham Bay; and at the copper property of the Endicott-Alaska Mining & Milling Co., at William Henry Bay. The Peterson mine, at Pearl Harbor, was also worked on a small scale during the summer. Elsewhere in this district mining and prospecting were practically at a standstill.

In the Ketchikan district mining was confined largely to Prince of Wales Island. The Rush & Brown copper mine and the Salt Chuck copper-palladium mine, on Kasaan Peninsula, were operated throughout the year, and the Dunton gold mine, near Hollis, was worked intermittently. Prospecting and development work were continued at the molybdenite property of the Treadwell Co., near Shakan.

JUNEAU DISTRICT.

MAINLAND.

PERSEVERANCE MINE.

The Perseverance mine of the Alaska Gastineau Mining Co., about 4 miles east of Juneau, was operated in 1919 on a basis ranging from 150,000 to 200,000 tons of ore a month, whereas the rated capacity of the mill is 10,000 tons a day. About 460 men were employed. The ore is being taken chiefly from levels 8, 9, 10, and 11. New construction and mine-development work have been greatly restricted, partly because of large increases in operating expenses and scarcity of labor, but also because development work is already considerably ahead of mining operations.

This project is a striking example of the hardship wrought upon the gold-mining industry by the increased cost of labor and supplies. According to data published in a paper by the manager of the Alaska-Gastineau Mining Co.,[1] the cost of supplies of all kinds advanced 35 per cent over the prewar cost in 1917 and 70 per cent in 1918, and it is believed by the writer that the advance reached 100 per cent in 1919. Wages increased 7 per cent in 1917 over the 1916 standard, 25 per cent in 1918, and, it is believed, at least 40 per cent in 1919. The cost of operation has therefore increased steadily during the last three years. The average cost of ore delivered to the mill over a period of four years is shown in the same paper to be about 48 cents a ton, and in view of the increasing costs in the last three years it is fair to judge that the present cost is considerably above this figure. To this must be added milling, shipping, smelting, and administrative charges, which will probably amount to 80 per cent of the cost of ore production. Data on the production of the Perseverance mine, published in monthly statements in the Engineering and Mining Journal, show that the net value per ton during 1919 ranged from 60 to 75 cents and averaged perhaps 70 cents.

ALASKA-JUNEAU MINE.

The Alaska-Juneau mine was operated continuously during 1919, employing about 225 men in the mine and mill. The new 8,000-ton mill, which was completed in 1917 and tried out in 1917 and 1918, was found to be less than 50 per cent efficient, and in 1919 much attention was given to improvements in milling practice. The flow sheet of the mill has been changed materially, and alterations have been made in the milling machinery. The chief improvements have been the introduction of hand picking of the ore as it comes from the

[1] Jackson, G. T., Mining methods of Alaska Gastineau Mining Co.: Am. Inst. Min. and Met. Eng. Trans., 1919, pp. 1547-1570.

12-inch grizzlies, the introduction of the old stamp mill into the flow sheet, and the rebuilding of the tube mills. The first change was necessary to prevent the handling of an excessive amount of waste; the second to avoid overloading the ball mills; and the third to correct poor construction in the tube mills. Milling difficulties are gradually being overcome by these changes.

The lode system at the Alaska-Juneau mine is cut by the Silver Bow fault, which strikes about east and offsets the ore body horizontally 1,000 feet, dividing it into a north and a south ore body. The ore between these two ore bodies lying along the fault is in the nature of fault-plane drag and is irregular in distribution. Present operations are being devoted mainly to cleaning up the old 400 stope, between the two main ore bodies, and to active development of the north ore body. The main haulage tunnel on the north ore body has been extended within 250 feet of the boundaries of the Alaska-Ebner property, and the 420 stope is being actively opened. It is planned to open a 430 stope and successive stopes to the northwest along the north ore body to the limits of the property. In addition, a main haulage way and three level tunnels have been driven in the south ore body, which will ultimately be developed as extensively as the north ore body. The ore mined in 1919 was taken in about equal amounts from the 400 and 410 stopes.

ALASKA-EBNER MINE.

After a period of inactivity of about a year, development work was resumed at the Alaska-Ebner mine of the United States Smelting & Refining Co., near Juneau, in the summer of 1919. A main tunnel running 3,200 feet in a northeasterly direction, thence eastward 1,400 feet, had previously been driven, intersecting the ore body. The present development work consists in the continuation of the main tunnel northeastward from the 3,200-foot point, with the intention of intersecting the ore body farther northwest.

JUALIN MINE.

Development work was continued at the Jualin mine, in the Berners Bay district, owned by the Jualin-Alaska Mines Co., but no ore was produced. Fifty-five men were employed—40 at the lower camp and 15 at the upper camp. At the lower camp work was continued on the 7,000-foot tunnel, which when completed will intersect the ore body at depth and will afford natural drainage for the mine. This tunnel is now being driven by three shifts operating two drills, advancing about 15 feet a day, and in September, 1919, had been driven 2,500 feet. If conditions are favorable, the tunnel should be completed by 1921.

The mine, at the upper camp, was pumped dry in 1919, after being flooded for a year and a half, and development and exploration work was continued. A short drift was driven on the 310-foot level, and several other drifts and crosscuts were expected to be completed before 1920. Exploration was carried on chiefly by means of two long drill holes. The first of these started from the southwest side of the property, on the 310-foot level, and was driven horizontally 1,000 feet to the southwest; the second, beginning at the east side of the mine, likewise from the 310-foot level, had been driven horizontally a little north of east about 1,250 feet in September and was to be continued to 1,500 feet. A third drill hole is planned, which will start from the northwest side of the mine and be driven west with a dip of 18° a minimum distance of 1,000 feet. In the lower tunnel drill holes will be driven every 500 feet at right angles to the tunnel on both sides to the limits of the property.

The mine is now well equipped for development and mining operations. A horse tram connects the wharf at Berners Bay with the lower and upper camps, and all three are connected by telephone. A wireless plant also affords communication with Juneau from the upper camp. Power at the upper camp is developed from Johnson Creek, which with an 80-foot head yields 100 horsepower. The water is turned back into the creek, and at the lower camp, under a head of 576 feet, 500 horsepower is developed. For use in winter, four 150-horsepower Petters semi-Diesel engines have been installed, and these are so adjusted that water may be used in conjunction with the engines when available. A 2,750 cubic foot compressor that uses 350 horsepower and will run 26 drills has also been added to the equipment. The stamp mill, which has a capacity of about 30 tons a day, with two amalgamators and two concentrating tables, at the upper camp, suffices for present mining operations, but plans for future operations include the erection of a new mill of greater capacity and the treatment on a large scale of low-grade disseminated ore, as well as the richer ore from the quartz veins.

The character of the mineralization at the Jualin mine and the number and character of the gold-quartz veins, so far as they were known in 1909, have been fully described by Knopf.[2] In addition to the three quartz veins known at that time, two others lying to the northeast, known as Nos. 4 and 5, have been discovered. The exact significance of these veins is not definitely known, but at present No. 4 is believed to be a different vein from Nos. 1, 2, and 3. Mill practice to date has demonstrated that about 80 per cent of the gold in the quartz veins is free. The remaining 20 per cent is contained with the concentrates, which are chiefly pyrite, with some chalcopyrite and galena.

[2] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, pp. 44-47, 1911.

PETERSON MINE.

Gold-lode mining on a small scale was continued on the Prairie claim, at the Peterson property, near Pearl Harbor, in 1919, and resulted in a small production. Recent work has consisted in mining two quartz veins from an open cut, practically at the surface, one about 4 feet and the other about 6 feet thick. The vein material is much weathered, disintegrated, and iron stained. A number of other croppings of vein quartz show on the property, but little exploration or development work has been done. It is certain, however, that a number of quartz veins are present.

The ore is carried by horse tram to a small 3-stamp mill which has a capacity of 1½ tons in 16 hours and is operated by water power. Here the ore is reduced and plated, and the concentrates are collected on a concentrating table. About 80 per cent of the gold is free and is recovered on the plates. The concentrates are shipped to Tacoma for treatment.

MINE OF ENDICOTT-ALASKA MINING & MILLING CO.

A low-grade copper mine is being developed by the Endicott-Alaska Mining & Milling Co. at William Henry Bay, on the southwest side of Lynn Canal, about 8 miles due west of Point St. Mary, at the entrance to Berners Bay. The bay is three-fourths of a mile long and 800 yards wide, is easy to enter, and is considered to be a good anchorage. Beardslee River enters at its head.

The mining property is about a mile west of the head of the bay, 160 feet above sea level. Development work has been in progress for about three years, and it will soon be possible to determine the amount and grade of available ore. Sixteen claims are held, of which 11 have been surveyed for patents.

The geology of the west side of Lynn Canal is complex and has so far been little studied. The strike of the rocks is roughly parallel to Lynn Canal, which is considered to lie along an extended fault zone. Hence correlation between the rocks on the east and west sides of the canal, as no paleontologic data are at hand and the lithologic sequence is imperfect, is hardly warranted. Along the shores of William Henry Bay the bedrock consists of a highly contorted limestone, in part thin bedded and in part more massive, with which some slaty argillite is interbedded, considerable chert, both massive and banded, greenstone flows, and clastic derivatives of the greenstone, classifiable under the general designations greenstone tuffs and graywackes. One of the greenstone derivatives consists of a conglomeratic rock, composed of rounded pebbles of limestone and other rocks embedded in and cemented by the tuffaceous material. Large dikes of diabase cut the stratified series of rocks. North of William

Henry Bay the greenstone tuffs and related rocks are the dominant rocks along Lynn Canal, continuing northwestward to the entrance of Chilkat Inlet, but limestones and other sedimentary rocks are present a short distance inland. South of William Henry Bay the rocks along the coast line are chiefly sedimentary, including argillite, slate, and limestone. It appears, therefore, that the boundary line between the greenstone series and the limestone-argillite rocks may run inland in a general northwesterly direction from William Henry Bay.

The country rock at the mine is in general greenstone tuff with interbedded lava flows, cut here and there by dikes. The tuffs and flows appear to be quite different in petrographic character. The tuffs, which in reality grade into graywacke, are greenish to greenish-gray rocks, of fine-grained texture and very difficult to classify in the hand specimen. Under the microscope they are seen to be clastic rocks composed mainly of angular to subangular grains of acidic plagioclase, chiefly albite and oligoclase-albite, in an indefinite groundmass or cement of sericitic and kaolinic material. They also contain grains of an igneous rock, which on account of the character of the plagioclase feldspar would be classed as sodic trachyte or albite andesite. Commonly these rocks are altered and show more or less calcite, quartz, epidote, and chloritic and sericitic material. In much of the rock the feldspars and other detrital constituents are bent, fractured, and veined by secondary minerals. The interbedded flows, which form a minor part of the sequence at this locality, are difficult to distinguish in the hand specimen from the clastic rocks, for they are likewise greenish and aphanitic. They are somewhat darker in color, however, and under the microscope are found to be basaltic. They are holocrystalline to somewhat glassy; are composed essentially of labradorite, augite (sometimes basaltic hornblende), and iron oxides; and are in places much altered, particularly in the feldspar, which has been changed to sericite. The only dike seen in the mine was a fine-grained holocrystalline rock composed of biotite and augite, with iron oxides and apatite, joined by interstitial albite. This rock is a sodic augite minette.

Along the mountain side southwest and west of the mine rocks of the same general character were seen. At an elevation of 1,200 feet, about S. 40° W. from the head of William Henry Bay, is a steep face of rock known as the Palisades. This rock is a fine-grained greenish-gray graywacke, which under magnification is seen to be composed of subangular to rounded grains of quartz, oligoclase-albite, and felsic rock, in a cement composed of epidotic, kaolinic, and sericitic material. Somewhat higher up, at an elevation of 1,900 feet, is a tuffaceous rock of the same general composition but of coarser grain and approaching more closely a true igneous rock in appearance, which continues up-

ward to a high flat on top of the spur. To the northwest along this ridge the country rock changes to a series of interbedded argillite and limestone.

A short distance northwest of the mine, in a little creek, tuffaceous graywacke of the same general character as that at the mine is exposed. Some of this rock shows considerable dynamic metamorphism, being sheared and rendered more or less schistose. One specimen was found to be essentially a fine-grained quartz-mica schist, although under the microscope the original fragmental character could still be observed.

The copper lode that is being developed is a vein composed chiefly of calcite, with considerable silica in the form of tiny veinlets of quartz and chalcedony. The copper ore is exclusively chalcopyrite and occurs with the quartz. The vein pinches and swells but probably averages 10 feet in thickness. The general strike is about N. 75° E. and the dip 80° S., but there are many local irregularities in attitude, due mainly to faulting. The ore carries only small quantities of gold or silver and is classed as a low-grade copper ore. The mine is being developed on the assumption that a 2 per cent copper ore can be produced.

The tunnel starts on the Bonanza No. 3 claim, cuts diagonally across the Endicott No. 2 claim, and enters the Endicott No. 3 claim. It is driven in a general southwesterly direction and intersects the vein 700 feet from the portal, at a point where the vein shows a displacement of 100 feet to the south, due to a fault. The tunnel follows the vein for 400 feet. Numerous small faults met in the tunnel show displacements of the vein ranging from practically nothing up to 10 feet and suggest step faults to take up the movement caused by larger displacements some distance away. At a distance of 1,100 feet from the portal a crosscut prospect tunnel has been started which will be driven northwestward, in the hope of cutting other veins.

The vein that is being explored in the tunnel crops out on the hillside west of the mine at an elevation of 500 feet. At this point the vein strikes about due east, stands vertical, and has a thickness of about 12 feet, with an 18-inch horse of country rock in the center. The vein material here also is practically all calcite with quartz veinlets and chalcopyrite. A little pyrite was seen, and this has oxidized and caused brown staining of the vein matter, particularly along fractures caused by later movements in the vein. The footwall side of the vein is slickensided and grooved, showing that considerable movement has occurred. The country rock is the same as in the mine. It is apparent that faulting is very prevalent and is likely to present some troublesome difficulties in mining.

No other surface outcrops of this or any other veins of mining importance have been found. On the ridge west of the mine, at an elevation of 2,300 feet, is a small calcite vein about 1 foot thick, which carries some quartz, chalcedony, and a little chalcopyrite, with secondary malachite. This vein, which strikes N. 78° E. and stands vertical, is now in part an open fissure, owing to decomposition and solution of the calcite.

Water power is utilized under a head of 300 feet to run a compressor for two drills. No reduction plant has yet been used, and therefore no ore has been milled or shipped. A 30-stamp No. 3 Austin gyratory mill, which was formerly used at the Sea Level mine, on Thorne Arm near Ketchikan, has been purchased and will be installed in 1920. A combination of Wilfley tables and oil flotation will be used. During the summer of 1919 a dock was in process of construction on the southeast side of William Henry Bay, with a depth of 4 fathoms at its outer end at low tide. Substantial buildings have been erected at the head of the bay, on the west side, and a wagon road connecting the bay with the mine has been built.

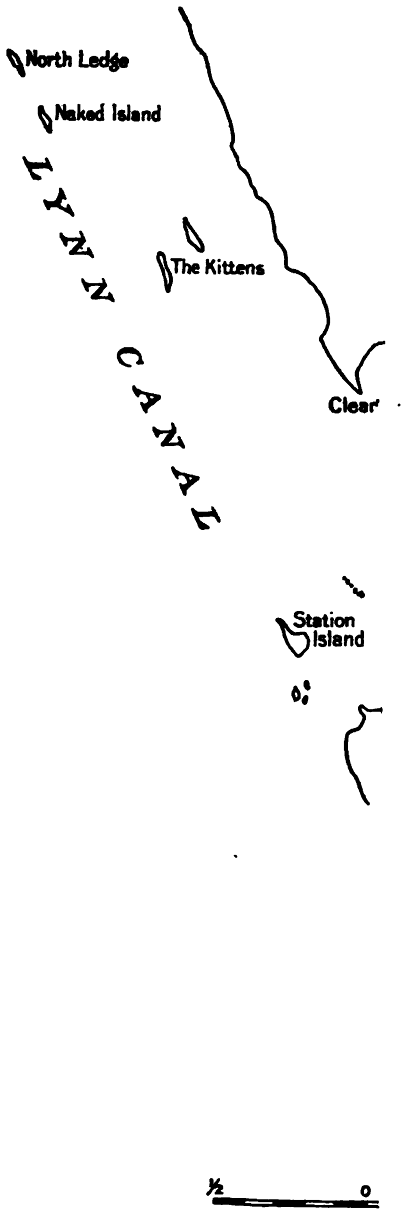
At the lower end of William Henry Bay, along the northwest shore, mineralization has occurred in the rocks at some places. The ore minerals consist for the most part of disseminated pyrites, but at one locality a deposit of sulphides, including arsenopyrite, chalcopyrite, and pyrite was seen in the cherty rocks.

DOUGLAS ISLAND.

The Ready Bullion mine, the one remaining mine of the Treadwell group that was not flooded by the cave-in of 1917, was operated during 1919 at a rate of output of about 24,000 tons a month. About 30 men were employed at the mine, and about 25 at the mill and cyanide plant. The mine now has levels at 2,000, 2,200, 2,400, 2,600, and 2,800 feet, and the main shaft has been extended nearly to 2,900 feet. Most of the ore being mined at present is being taken from the four stopes of the 2,200-foot level, but some is being drawn from the 2,400-foot level. The latest work is the cutting out of three stopes on the 2,600-foot level, preparatory to drawing ore.

The ore is treated at the Ready Bullion 150-stamp mill and cyanide plant. The ore, after being crushed to 40 mesh by the stamps, is conveyed to a small ball mill which reduces the first product to 200 mesh. The oversize is separated by classifiers and returned to the ball mill. The 200-mesh product is conveyed to the cyanide plant, where it is cyanided, washed, filtered, dried, and retorted.

The Treadwell Co. is now operating a 2-ton electric furnace for making steel for its own use in steel castings. Scrap iron collected around the plant has so far been utilized as the raw product, but considerable hematite purchased in Seattle has also been used as a



SKETCH MAP OF M

decarbonizer. The carbon content of the steel is reduced to 0.3 to 0.5 per cent. The other necessary ingredients, including ferrosilicon, chrome, manganese, and aluminum (used as deoxidizer), are also purchased. Local magnetites from Haines and Port Snettisham have been tried in place of hematite, but they require too high temperature and too much coke. Both these magnetites have been found to contain considerable TiO_2, and that from Port Snettisham carries some P_2O_5. A few iron and brass castings have also been made.

ADMIRALTY ISLAND (FUNTER BAY).

GENERAL FEATURES.

Funter Bay, on Admiralty Island, is a well-known harbor on the east side of Lynn Canal, practically at the junction of Lynn Canal, Chatham Strait, and Icy Strait. It is a safe and convenient anchorage, and on account of the frequency of stormy weather on Lynn Canal and Chatham Strait it is much visited by small boats. The bay has a general northeasterly trend and is about 2 miles long and three-fourths of a mile wide at the entrance. A cannery and a post office (Funter) have been established on a point on the north side of the bay. Funter Bay is but 18 miles from Juneau in an air line, but 50 miles or more by water.

The shore line of Funter Bay is in general a cliff that rises 20 feet or more above sea level and is bordered by a low-terraced platform which rises gradually to the hills behind. On the northeast side of the bay this platform connects with low hills, but on the southeast side the lowland area gives way to high mountains that rise abruptly to an elevation of nearly 4,000 feet. Both lowlands and mountains are timbered, the mountains up to an elevation of about 2,500 feet.

The lode properties lie chiefly along the southeast side of the bay, beginning at the shore line and extending up into the high hills. Gold-quartz veins were discovered at this locality in 1887, and a number of properties have been held since that time. Many quartz veins have been discovered and a good deal of prospecting has been done, but as yet there has been little mining. At the present time development work is being done on the claims of the Admiralty-Alaska Gold Mining Co. and prospecting is being continued on the Nowell-Otterson group of claims. The former embrace two groups of claims, a lower and an upper group, about midway of the bay on the southeast side; the latter adjoin these claims on the southwest. A good-sized stream, Mountain Creek, lies between the two properties. The general position of these two groups of claims is shown on the accompanying map (Pl. IV).

The claims, particularly those of the Admiralty-Alaska Gold Mining Co., have been examined a number of times by different members

of the Geological Survey, and two reports[3] have been prepared and published. No extensive study of the regional geology has so far been attempted, but the different quartz veins have been fairly well described. The present notes are only supplementary to the earlier reports.

The general geology has been briefly described by Eakin[4] as follows:

The rocks of the Funter Bay district include a highly altered bedded series, dominantly greenstone schist and subordinately limestone or marble, and a few small dikes of diabase, andesite, and diorite, which cut the bedded rocks at wide intervals. The schistose cleavage of the metamorphic rocks is generally parallel with the bedding planes. Locally intense crumpling and close folding on a small scale are apparent, but in general the bedded rocks lie in broad and gentle folds. Over considerable areas both schistosity and bedding are near the horizontal. Joint systems on both large and small scales cut the bedded rocks at high angles with the schistosity and bedding or near the vertical. The major joint planes in places persist for hundreds and even for a thousand feet or more with great regularity in strike and dip. Such large fractures were probably accompanied by some differential movement between the blocks which they separate, but there is no definite indication of the maximum displacement. These planes are generally marked by quartz veins, which range in thickness, in the different individuals observed, from mere films to nearly 60 feet. At one locality four approximately parallel veins were measured in a section 330 feet across, whose thickness aggregated 90 feet. Obviously the introduction of this amount of quartz in a narrow section involved displacement of masses of the rock. T-shaped and L-shaped bends in some of the veins indicate differential movements amounting at least to the thickness of the veins. Other veins, which gradually thin out to their ends, do not have this significance. Faults later than the veins and offsetting them occur only here and there, according to present evidence.

The metamorphism of the bedded rocks is for the most part of regional character and of earlier age than the igneous dikes or the quartz veins, which are unsheared. Later metamorphic agencies have affected the bedded rocks locally, adjacent to the quartz veins, resulting in silicification and bleaching of the greenstone schists, accompanied by the introduction of sulphide minerals and in places of gold. Such minerals also occur in bands of greenstone schist without associated quartz veins at two localities, but they are not believed to represent a distinct period of mineralization.

The schists of the Funter Bay area, grouped by Eakin under the general designation of greenstone schist, consist of a variety of rock types, including chlorite schist, mica schist, quartz-chlorite schist, quartz-chlorite-mica schist, zoisite-chlorite schist, albite-zoisite schist, albite-chlorite schist, and albite-mica schist, as well as nonschistose blocky rocks of the same general character, usually carrying little mica. Among the metamorphic rocks are also to be found gneissoid rocks, including albite granite gneiss and albite syenite gneiss. Normal dioritic or andesitic rocks were not observed by the writer, but a variety of other dike rocks containing plagioclase high in soda were recognized. These are chiefly albite granite, albite syenite (or albite diorite), and albite trachyte. One dike of olivine diabase was noted.

[3] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 147-150, 1906. Eakin, H. M., Lode mining in the Juneau gold belt: U. S. Geol. Survey Bull. 662, pp. 84-92, 1918.
[4] Eakin, H. M., op. cit., pp. 84-85.

The above is by no means an exhaustive list of the different varieties of rocks found at Funter Bay but is given chiefly to illustrate a feature of these rocks that has been generally overlooked, namely, their sodic character. All the acidic and intermediate types of intrusive rocks examined by the writer contain albite or oligoclase-albite plagioclase feldspar, and albite is also of common occurrence among the schists and gneisses. This feature is of more than passing interest when considered in relation to the sodic character of the intrusive rock at the Treadwell mines, on Douglas Island, about 15 miles to the east.' It is not unlikely that mineralization at these two localities took place at the same general period and had a similar origin.

CLAIMS OF ADMIRALTY-ALASKA GOLD MINING CO.

The Admiralty-Alaska Gold Mining Co. holds 52 claims, of which the principal ones are shown on the accompanying sketch map (Pl. IV). These claims lie in two groups, a lower group on the low terrace leading back from the beach, and an upper group on the mountain slope to the southeast. In the lower group the principal lodes are the Tellurium, King Bee, Uncle Sam, and Lone Star; a number of smaller veins also occur. The upper group includes a large number of veins, among the most valuable of which are the Blanket lode, the veins on the several Heckler claims, including the Big lode and the Washington lode, the Devil Club lode, and the Patterson lode. Both the lower and the upper veins have been described adequately by Eakin, and no new work has been done on their surface outcrops in the meanwhile.

A tunnel is now being driven from the end of the tram line to prospect the quartz veins of the upper group. This tunnel starts about a mile from the beach, at an elevation of about 250 feet, and is being driven S. 65° E. with the intention of crosscutting at depth the veins on the Lowhee No. 2, Mountain Kink, Pungle Up, Washington, and Heckler claims. Work was begun on this tunnel in the fall of 1918, and by midsummer of 1919 it had been driven about 800 feet. One drill is being used.

A compressor plant, with a capacity of 12 drills, has recently been installed. Water power under a head of 500 feet, delivered to the compressor in a 6-inch stream, is utilized. A sawmill has also been built. From 5 to 15 men were employed during the summer of 1919.

The tunnel is driven in a greenstone schist, which differs in character in different parts of the tunnel. At the face in 1919, about 800 feet from the portal, it consists of a recrystallized rock, somewhat schistose in appearance, composed essentially of a mixture of zoisite and chloritic material, chiefly pennine, together with considerable quartz and some pistacite and titanite, and would be designated a zoisite-chlorite schist. The dip of the schist in the tunnel

is in general away from the beach. About 400 feet from the portal a small ore body consisting of a sheared mixture of quartz and schist, with about 8 inches of milky quartz on the hanging wall, was intersected. This vein and its accompanying zone of shearing is parallel with the cleavage of the schist. The sulphide minerals include pyrite, pyrrhotite, and a little chalcopyrite. The hanging wall was found to be a fine-grained igneous rock, with a pronounced flow structure, composed essentially of unaltered oligoclase-albite in tiny laths, forming a felty trachytic groundmass, and an interstitial filling of chloritic material, derived probably in part from rock glass. Some larger laths or phenocrysts of oligoclase-albite are partly altered to epidote and calcite. Secondary quartz, epidote, and calcite are present. This hanging-wall rock is a sodic trachyte.

No other quartz veins of any importance have so far been crosscut, but it is planned to continue the tunnel until the Heckler Blanket lode, the Big lode, and other veins that crop out on the Heckler group of claims are intersected. No accurate base map of the property has been made, but it is estimated roughly by the writer that a 2,000-foot tunnel will be required to reach the Heckler Blanket vein, if the strike and dip shown at the outcrop continue below the surface to the level of the tunnel. The strike and dip of the Big lode are not sufficiently well known, owing to the lack of stripping at the outcrop, to justify a guess as to how far the tunnel will have to go to cut this large body of quartz. The vein crops out farther southeast than the Heckler Blanket vein, but the dip may be lower, thus partly or wholly compensating for the greater surface distance.

NOWELL-OTTERSON CLAIMS.

The Nowell-Otterson group of claims lies southeast of the property of the Admiralty-Alaska Gold Mining Co. and includes 19 claims stretching from Funter Bay to the top of the mountain to the southeast. The general position of these claims is indicated on the accompanying sketch map (Pl. IV). A good trail has been built from the bay to the top of the mountain, making these claims easy of access.

On the Winona claim, at an elevation of 675 feet, a tunnel 64 feet long has been driven on two quartz seams, which strike about N. 55° E., conformably with the country rock, and dip southeast. The upper of these seams is fairly persistent and ranges from 6 to 24 inches in thickness; the lower seam is lenticular and discontinuous. The footwall is graphitic chlorite schist, and the hanging wall a quartz-mica schist. The quartz is iron stained and carries stringers of country rock. Some pyrite and pyrrhotite were seen in the quartz.

On the Chatham claim, at an elevation of 1,050 feet, a tunnel has been driven 200 feet and crosscuts four thin quartz seams, from 2 to 4 inches wide, which strike N. 45° E. and dip 45° NW., thus cutting

almost directly across the structure of the country rock, a quartz-mica schist. The quartz carries pyrite, pyrrhotite, and gold.

To the east of the tunnel, on a small creek, several small quartz veins of similar character are exposed. A small shipment of ore (about 5 tons) from one of these veins, which ranges in thickness from 8 inches to 2 feet, was valued at $120 a ton, and a second sample at a later date ran $80 to the ton. At least 10 such small veins, most of them measurable in inches, are exposed in the creek. The quartz carries pyrite, pyrrhotite, and in places a little galena, in addition to the gold.

The vein of most interest on the Nowell-Otterson group is the Big Thing lode, which crops out on the line between the Francis and O. K. claims at an elevation of 3,100 feet and has been traced 800 feet to the north and over 1,500 feet to the south. The vein, which strikes about N. 20° W. and dips steeply to the east, lies parallel with the schistosity of the country rock. The hanging wall is a chlorite schist composed of chloritic material, quartz, calcite, and epidote. The footwall is a graphitic schist. On the line between the O. K. and Francis claims about 20 feet of quartz is exposed, with a horse of schist in the center of the vein. The quartz is heavily iron stained and is mineralized by iron sulphides (pyrite and pyrrhotite), galena, and hematite. It is characteristic of these sulphides to be concentrated in pockety masses in the quartz. The owners aver that the average of assays so far made is about $5 to the ton in gold.

On the Two Shaft claim, about 1,800 feet north of the outcrop just described, at an elevation of about 3,050 feet, a vein of quartz from 15 to 25 feet thick crops out and is believed to be the continuation of the Big Thing lode. The country rock here is a quartz-mica schist, and the vein strikes about N. 15° W. and dips steeply to the east, as at the other locality. The quartz is of the same general character as the quartz above described, but more galena is present, and some chalcopyrite was also seen. A good deal of free gold may be seen with the naked eye, and it is apparent that some of this material is high-grade ore.

Another vein, distinct from the Big Thing lode, also crops out on the Two Shaft claim, some distance west of the one just described, at an elevation of about 2,750 feet. This is a smaller vein of quartz, about 30 inches thick, striking N. 20° W. and dipping steeply to the east, which lies comfortably with the schist and is heavily impregnated with sulphides. The quartz where unaffected by the mineralizing solutions is white and milky, but elsewhere it is heavily iron stained. Pyrite, galena, chalcopyrite, and specular hematite are found with the quartz. Green malachite staining and to a lesser extent blue azurite discoloration are apparent. An irregular body of calcite cuts transversely through the vein and appears to represent

a later phase in the sequence of mineral deposition. This vein carries very little gold but is reported by the owners to give high assay results in silver and lead.

A number of other quartz veins crop out on this mountain in the vicinity of the O. K., Two Shaft, and Summit claims, but little prospecting has been done on them, and therefore little is known of their character and extent.

KETCHIKAN DISTRICT.

PRINCE OF WALES ISLAND.

SHAKAN MOLYBDENITE LODE.

A molybdenite lode was opened in 1917 by the Alaska Treadwell Mining Co., and development work has continued to the present time, although no ore has yet been shipped. This lode is about three-fourths of a mile south of Shakan, at an elevation of 600 feet, at the north end of Prince of Wales Island, on the east side of a small stream that enters Shakan Bay.

The country rock consists of tuffaceous sediments intruded by diorite. The lode is in diorite, which varies somewhat in character and composition but in general is composed of zonally grown plagioclase feldspar, ranging from albite on the rims to bytownite in the centers of the crystals, and with an average composition perhaps of andesine; a small amount of orthoclase; considerable hornblende; and biotite, augite, iron oxides, and apatite. Being composed essentially of plagioclase feldspar and hornblende, this rock is classed as a hornblende diorite. Pegmatite is present in dikes and veins cutting the diorite and is in fact related genetically to the molybdenite in the lode. The pegmatite is composed essentially of orthoclase feldspar and quartz, with accessory sphene and small amounts of secondary sericite, chlorite, and epidote.

The vein at its maximum is 6 feet thick, with a strong, clean-breaking hanging wall and an indistinct footwall. It varies considerably in strike and dip, as is shown by the crookedness of the main tunnel which follows the vein. The average strike is about N. 70° W. and the dip ranges from 10° to 25° S. Considerable faulting is apparent, particularly along the hanging wall, where in places the vein matter for 6 inches or more has been reduced to a fault gouge. Some of the best of the ore has been taken from this zone along the hanging wall. The gangue of the vein is partly quartz and partly pegmatitic material, and these two appear to grade into one another, indicating that at least a part of the quartz is of primary origin. The sulphide minerals in the gangue include molybdenite, pyrite, pyrrhotite, and chalcopyrite. The molybdenite is in some places scattered through the quartz and pegmatite and in others more or

less concentrated, particularly in the gouge zone. Pyrite and chalcopyrite are distributed throughout the gangué, but pyrrhotite is most often found in pockets or kidneys. The paragenesis of the sulphide minerals has not been deciphered.

A tunnel, now driven 360 feet, is the main underground development work. At 250 and 300 feet from the portal cross faults were met, the first striking N. 10° E. and the second N. 10° W., with offsets at both places. The molybdenite content of the vein becomes very low beyond the 300-foot point in the tunnel, and at this point the direction of the tunnel was changed to one somewhat south of the strike on the working hypothesis that the true vein at the 300-foot point has been replaced through faulting by a barren quartz vein. It is equally possible, however, that a molybdenite ore shoot in the vein has been terminated by the fault, and that the vein exposed beyond the fault is a barren zone of the same vein. In this event, further drifting on the vein or sinking an inclined shaft down the dip will afford the greater chance of discovering ore.

A tramway has been constructed from the portal of the tunnel across the small stream above mentioned and down the opposite side of the valley to tidewater. A small dock has also been built. All the mining has so far been done by hand, but in September, 1919, a compressor plant was at the dock awaiting installation. Six men, working in two shifts, were at work at the time of the writer's visit.

RUSH & BROWN MINE.

The Rush & Brown mine, about half a mile west of Lake Ellen, at the head of Kasaan Bay, was the only copper mine in southeastern Alaska that was operated in 1919. The property includes two ore bodies that have been developed to a productive basis and a number of others that have not been explored. The larger of the two productive ore bodies is a contact-metamorphic deposit of copper-bearing magnetite, and the smaller a fault-zone deposit, with chalcopyrite as the chief sulphide. The former is of too low a grade to be worked at the present price of copper; but the latter carries a higher grade of copper ore and also considerable gold and silver, and in recent years mining has been confined to this deposit. Eight men were employed in the mine in 1919, and several others at the surface.

The contact-metamorphic deposit lies in contact rock between diorite and graywacke, trends about due east, and stands practically vertical, plunging perhaps at a high angle to the north. The ore has been exposed in a glory hole and numerous drifts from it to a depth of 140 feet, for a distance of about 200 feet, and shows a width ranging from 50 feet at the west end to 125 feet at the east end. The deposit, however, is irregular in outline and variable in ore content, owing to the inclusions of numerous horses of country rock. Both

ore zone, however, or the zone within which the discovery of ore shoots may be expected, is believed to be at least 250 feet wide and is thought to extend in a direction about N. 75° W.

This deposit, unlike most of the other commercial ore deposits of Kasaan Peninsula, occurs in an area of coarse-grained intrusive rock, which has been mapped by Wright[5] under the general designation granitic intrusives. Such intrusive rocks invade the Paleozoic sedimentary rocks of Kasaan Peninsula at many localities, occurring as small and large bodies of varying petrographic character. The normal type of these rocks is a diorite, low in quartz and orthoclase, but numerous other facies have been evolved by magnetic differentiation. In the acidic differentiates low potassium and high soda content expresses itself through the formation of sodic granite and syenite, the chief feldspar of which is albite, in place of orthoclase, the normal type in such rocks. Much diversification is apparent among the basic types of differentiated rocks, although few of these have been described in any detail. This differentiation is well illustrated at the Salt Chuck mine, where the country rock is in general a pyroxenite, with gabbroic and gabbro-pegmatitic phases. Wright referred to the country rock at the Salt Chuck mine as a gabbro, but in his petrographic description he showed clearly that the plagioclase feldspar constitutes only from 5 to 10 per cent of the rock. It seems better, therefore, to designate the intrusive rock at the mine pyroxenite, remembering, however, the gradual transition to the true gabbroic intrusives in this vicinity. The chief rock-forming mineral is augite, and the subordinate constituents are biotite, iron oxides, plagioclase, apatite, and titanite, though not all of these are invariably present in any one specimen. Biotite in particular is variable in distribution, and much of it occurs as large splendent crystals. The pyroxene and plagioclase are in places much altered, the alternation resulting in the development of rocks rich in epidote and in chloritic and sericitic material.

The ore minerals consist of copper sulphides, distributed in grains and small patches as ore shoots in the pyroxenite. Bornite is the chief copper mineral, but a small proportion of chalcopyrite also occurs locally. Chalcocite and covellite are both present, as alteration products of the bornite and also of the chalcopyrite. Finely disseminated chalcocite and native copper have been reported by Knopf[6] as occurring in some drifts about halfway between the upper and lower tunnels, leading from a connecting winze. Practically no gangue minerals are found with the ore. In addition to copper, gold, silver, palladium, and platinum are recovered.

[5] Wright, C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 87, p. 73, 1915.

[6] Knopf, Adolph, Mining in southeastern Alaska, 1910: U. S. Geol. Survey Bull. 480, p. 101, 1911.

The metallic content of the Salt Chuck ores was shown in a table of analyses by Campbell,[7] and this table, with the addition of three determinations of concentrates, is given below.

Metallic content of Salt Chuck ores.

[Copper in per cent; other metals in ounces to the ton.]

	Copper.	Gold.	Silver.	Platinum.	Palladium.
Gloryhole	1.92	0.07	0.17	0.41	
150-foot level	1.08	.07	.24	.18	
Bottom of winze	1.28	.05	.24	.17	
Average of ore analyses	1.427	.063	.217	.253	
Gabbro	.06	.01	.10	.01	
Chalcopyrite	27.66	.11	2.08	1.01	
Concentrates	43.81	1.17	4.60	3.54	
Concentrates (Eng. and Min. Jour., Sept. 27, 1919)	36.96	1.27	6.10	0.10	2.93
Concentrates				.04	2.56
Concentrates	39.41	1.20	5.18	.04	3.38
Average of concentrates	40.06	1.213	5.293	3.147	

From these data it is possible to estimate the percentage recovery of the precious metals in the concentrates. If the concentrates average 40.06 per cent of copper each ton of concentrate will contain 801.2 pounds of copper. Then, as the average copper content of the ore is 1.427 per cent, each ton of ore contains 28.54 pounds of copper; and the number of tons of ore used to produce 1 ton of concentrates, on the assumption of a copper recovery of 100 per cent, would be $801.2 \div 28.54 = 28.07$ tons. The recovery of gold, silver, and platinum metals in ounces per ton is obtained by dividing their respective figures in the "average of concentrates" by 28.07; and the ratio of the resulting quantities to the corresponding quantities given in the "average of ore analyses" yields the percentage of recovery for the precious metals in terms of the assumed 100 per cent recovery of copper—that is, gold 68 per cent, silver 87 per cent, and platinum metals 44 per cent. The exact percentages of precious metals recovered are obtained by multiplying these computed percentages by the true recovery of copper.

On reducing the copper percentage to troy ounces per ton and comparing the result with the figures for the precious metals, it appears that the ratio of the copper to the gold, silver, and platinum metals is 6,607, 1,918, and 1,645 to 1 respectively, and that the ratio of the gold to the silver and platinum metals is roughly 1 to 3 and 4 respectively. Of course, an average of three assays affords no basis for any exact deductions, but nevertheless these figures are useful in giving a general idea of the occurrence of these metals.

[7] Campbell, D. G., Palladium in Alaska lode deposits: Min. and Sci. Press, vol. 119, pp. 520-522, 1919.

A little free gold may be seen in some of the ore, but the disparity between the recovery of gold and the recovery of platinum metals leads to the belief that a considerable part of the gold is chemically combined or mechanically held with sulphides. The high content of silver relative to gold indicates an additional source of silver besides that alloyed with gold, and the high silver recovery indicates that the silver is present as some silver or copper-silver mineral, probably a sulphide or sulpho-salt, which is highly adapted to the flotation process. Possibly it occurs in both these forms. The high content but low recovery of platinum metals, when considered in the light of the known relationship between copper and platinum metals in these ores, indicates that the larger part of the platinum metals are held mechanically by the copper minerals and are liberated in the ball mill. The ratio of palladium to platinum appears to vary considerably but is believed to average about 50 to 1.

The analysis of the chalcopyrite is also of some interest. Gold, silver, and platinum metals are found in the chalcopyrite, and although this fact does not permit any inferences as to the state of existence of the precious metals, it serves partly to corroborate the nfluences above drawn. The ratio of gold to silver to platinum metals in the chalcopyrite is about 1 to 19 to 9, whereas in the average of ore analyses it is 1 to 3 to 4. The higher ratio of silver to gold in the chalcopyrite analysis is probably due in part to the lower content of gold in the chalcopyrite than in average ores, owing to the presence of a certain percentage of free gold in the country rock; but probably it is due more largely to the higher content of silver in the chalcopyrite, as a result of the presence of intergrown silver or copper-silver sulphides. The higher ratio of platinum metals to gold in the chalcopyrite analysis is interpreted as evidence that more of the platinum metals are associated with the copper minerals than occur free in the country rock, thus corroborating the relationship that appears to exist between the copper and platinum metals in the mine. The analyses above given show from 0.13 to 0.21 ounce of platinum metals to the ton for each 1 per cent of copper; the lower figure is more probably representative of the average.

The mode of formation of this deposit and the distribution of the ore present some puzzling features. The country rock, though mainly pyroxenite, shows gabbroic and gabbro-pegmatitic phases, and at the west end of the glory hole a basic dike 4 feet thick cuts the pyroxenite. Considerable epidote also occurs, in part replacing the minerals of the country rock and in part as traversing veinlets. The ore is evidently later than the dike, for a bornite-chalcopyrite ore shoot cuts directly across the dike. The country rock is much fractured, but there is no particular system to the fractures, and no

large displacements. The general trend of the zone of the fractured and faulted rock, however, is believed to be about N. 75° W.

At first sight the bornite and chalcopyrite may be regarded as ores segregated from the gabbro mass. The copper minerals do not appear to follow the larger fracture planes to the extent that might be expected in an ore deposited from circulating waters. The ore occurs in shoots, which appear more or less independent of the rock fractures, and the bornite is found as disseminated particles within these shoots, some of it in massive country rock at some distance from any apparent openings. Also, free gold was observed which had been drawn out and elongated by faulting subsequent to its deposition, showing that at least some of the fracturing movements occurred after the deposition of the ore. On the other hand, some of the copper ore, particularly the chalcopyrite, lies along the fractures in such a manner as to show clearly that it entered the rocks and was deposited subsequent to the fracturing. Moreover, where the bornite occurs in massive, unfractured pyroxenite, the rock-forming minerals of the pyroxenite are noticeably altered, chiefly to epidote, with less chloritic material; and the degree of this alteration appears to be a function of the amount of ore present. Finally, the texture of the ore as seen under the microscope belies the appearance of primary character which is seen in hand specimens. The country rock contains many minute cracks, adequate for circulating ore solutions, and the ore itself shows that it has entered the rock in this manner and replaced the rock minerals. Hence, though all the details of the ore deposition can not be explained, it seems certain that this is at least an epigenetic deposit—that is, it was formed later than the containing country rock.

The presence of chalcocite, covellite, and native copper point unmistakably to enrichment, due to the action of meteoric waters working downward from the surface. The chalcocite and native copper observed by Knopf[a] were at a depth of about 200 feet below the surface and shows that enrichment has occurred at least to this depth. This is rather remarkable for southeastern Alaska, for it has generally been believed that in that region the recent glaciation had removed the zone of oxidation and practically all of the secondary sulphide zone. It would be of interest to know whether this supergene enrichment is a remnant representing a preglacial secondary sulphide zone, or whether it has occurred in postglacial time. In either case the theoretical conclusion is that the ore will be found to become leaner with depth, but it is doubtful if this feature will prove of much economic importance, as the percentage of secondary sulphides appears to be relatively small.

[a] Knopf, Adolph, Mining in southeastern Alaska, 1910: U. S. Geol. Survey Bull. 480, p. 101, 1911.

The Salt Chuck ore deposit has been developed at the surface by a small glory hole and an open cut almost adjoining it on the east, and underground by a tunnel 300 feet long which at its face opens upward through a stope into the glory hole. Near the face of this tunnel a winze has been sunk 200 feet, connecting with a new lower tunnel, and the winze has been continued upward as a raise for 90 feet. A tram 2,200 feet long has heretofore been used to transport ore from the mine to the mill. The new lower tunnel, 1,225 feet long, has now been completed and will be used as the main oreway.

Ore is now being taken from the stope that connects the upper tunnel with the glory hole. One of the difficulties of mining operations at this property is the irregular distribution of ore stopes. There are practically no data on which to base prospecting, for there is no vein or well-defined shear zone, and the stopes occur seemingly at random. There is a limit to the mineralized zone, which probably coincides with the limit of the faulted and fractured area of peridotite, but this is neither sufficiently definite nor sufficiently circumscribed to be of value in laying out the mine. That such a limit exists is shown in the new lower tunnel, which is 1,225 feet long and in which no ore was seen until the tunnel had been driven 990 feet. The horizontal sequence in this tunnel from the portal inward is as follows:

Sequence in lower tunnel of Salt Chuck mine.

	Feet.
Barren country rock	990
Zone of disseminated bornite	15
Barren country rock	15
Zone of disseminated bornite	30
Barren country rock	170
Zone of disseminated ore, chiefly chalcopyrite, subordinately bornite	5

It is not known in what manner the ore zones shown are cut by the tunnel, and the thicknesses given, therefore, may or may not represent true cross sections of the shoots.

The ore is reduced in a concentration and flotation plant on the property. Power for the mill and mine is generated partly by water and partly by means of a 75-horsepower Fairbanks-Morse semi-Diesel engine. Water is taken from a 31-acre lake and delivered to the wheels in a 10-inch stream, under a head of 179 feet; and when the supply is adequate, 220 horsepower is generated by this means. The supply of water, however, is usually inadequate, and the engine has to be run much of the time. This constitutes one serious handicap to economical mining.

Ore is delivered at the mill into a 175-ton storage bin, from which it goes through two sets of jaw crushers and is reduced to about 2-inch size. This material is then dumped into a 75-ton bin, whence it is fed automatically to a Worthington ball mill, with a rated capacity of 60 tons in 24 hours. Final grinding is at present accomplished by

this operation, but the ball mill is overtaxed, and it is planned to introduce rolls between the crushers and the ball mill, reducing the product to 1¼-inch size before delivery to the mill. This will be a great improvement. The pulp from the ball mill goes to a classifier, from which the oversize is conveyed back by a scraper belt to a trommel, while the fines flow off and are raised by a bucket elevator belt to the flotation cells. The oversize from the trommel goes back to the ball mill, and the undersize to a Biester-Overstrong concentrating table. The flotation plant consists of five cells, in which are used mixtures of oil of pine, pine tar, creosote, and coal tar. About 90 per cent of the ore is caught in the first two cells. From these the concentrate goes to Callow cones, where it is largely dewatered. Final drying is accomplished in filter presses, where the moisture is drawn off by compressed-air suction. A shipping product containing only 10 per cent of moisture is said to be produced.

DUNTON MINE.

The Dunton mine, the property of the Dunton Gold Mining Co., is on Harris Creek about 2 miles from the post office of Hollis, at the upper limit of high tide. Harris Creek is navigable for small boats at high tide up to the mine. This property lies at the south end of a zone of mineralization, which extends somewhat east of north for 4 or 5 miles, reaching some distance north of May-be-so Creek. The Dunton property includes two claims along this mineralized zone.

The country rock in this vicinity, according to Chapin,[9] consists of "a complex assemblage of igneous and sedimentary rocks. The bedded rocks include tuff, breccia, schist, limestone, black slate, argillite, and graywacke and are cut by a large boss of quartz diorite and associated porphyritic dikes." The country rock at the mine is a graphitic slate, which ranges in strike from east to N. 30° W., averaging perhaps N. 30° E., and dips 12°–35° SE. The slate is much faulted and slickensided, but the displacements are for the most part parallel with the rock structure. The highly graphitic character of the slate is particularly evident along the slickensided surfaces. Fine-grained dike rocks, in places porphyritic, also intrude the country rock more commonly parallel with the structure of the slate than otherwise.

The mineralized zone on which the Dunton mine is located extends about 2 miles to the northeast and then changes in trend or joins another zone which extends northward to May-be-so Creek. The northeastward-trending zone ends at the Hollis group of claims, and the northward-trending zone, which begins at that point, includes the Crackerjack and Ready Bullion lodes, to the north, although these

[9] Chapin, Theodore, Mining developments in the Ketchikan district, 1917: U. S. Geol. Survey Bull. 692, p. 87, 1919.

two lodes appear to be separate veins. According to Chapin[10] three veins, known as the lower, middle, and upper veins, are recognized at the surface in this mineralized zone. "These are approximately parallel and form a lode system following intrusive porphyry dikes." The vein that is mined at the Dunton mine is the upper vein. A 10-inch quartz seam lies 15 feet below this, and a barren quartz vein lies 150 feet lower.

The Dunton lode consists of a number of quartz stringers which form a mineralized zone in and conformable with the slate. The thickness averages about 7 feet, though increasing locally to 12 feet. The individual quartz stringers range in thickness from a few inches up to 1 or 2 feet. Much faulting has taken place parallel with the vein, crushing and slickensiding the ore and country rock but causing no apparent displacement. Dikes run parallel with the vein, more commonly on the hanging than on the footwall side, but here and there cutting across the lode. Many of these dikes are mineralized with pyrite, but they do not constitute minable ore. They have been greatly altered to secondary products, and the original petrographic character could not be inferred. The vein pitches on the average about 28° SE.

The quartz is mineralized by auriferous pyrite, gold, and a little galena. Good ore occurs in shoots, which appear to be localized in parts of the vein where the dip is lowest. The ore is best where pyrite is most abundant. Locally the slaty country rock carries some gold, particularly where it is pyritized. About 75 per cent of the gold is free, and the concentrates consist almost wholly of pyrite. Taken as a whole, the quartz and mineralized country rock, which together form the ore, would be classed as a low-grade gold ore, but only ore from the richer shoots is mined. This gives a higher-grade ore but limits the available tonnage.

The mine is developed by an adit 364 feet long, which follows down the dip of the vein. Four drifts—a short one at 70 feet, another at 100 feet, a third at 180 feet, and the fourth at 250 feet—constitute the chief development work. The ore is reduced by a 5-stamp Chalmers & Williams mill, with plates and concentrating table, operated by three vertical turbines generating together 90 horsepower. The mill has a capacity of 12 tons a day. Water is brought from Harris Creek through a 250-foot flume and delivered with a head of 13 feet.

[10] Chapin, Theodore, op. cit., p. 88.

NOTES ON THE SALMON-UNUK RIVER REGION.

Compiled by J. B. Mertie, Jr.

INTRODUCTION.

The Salmon-Unuk River region, in southeastern Alaska, is a trapeziform area of about 1,800 square miles, lying between parallels 55° 50′ and 56° 30′ north latitude and meridians 129° 50′ and 131° 10′ west longitude. The international boundary between Alaska and British Columbia, extending in a general northwesterly direction along the crest of the Coast Range, delimits the area on the northeast. This district is adjacent to tidewater, reaching Behm Canal on the southwest side and Portland Canal on the southeast side. On account of mining activity in the vicinity of Portland Canal, the southeastern part is referred to by Americans as the Portland Canal district and by Canadians as the Portland Canal mining division.

This portion of southeastern Alaska, along the international boundary and adjacent to the intrusive rocks on the Coast Range, has been recognized for years as favorable for the occurrence of mineral deposits, and in the last 22 years numerous more or less promising deposits have been discovered and located. The present renewal of public interest in this part of Alaska and British Columbia is due mainly to the recent successful development of some of these deposits at the head of Portland Canal, on the Canadian side of the boundary, and the promise which such development holds forth for the subsequent exploitation of similar deposits that lie along this same zone of mineralization.

A considerable amount of topographic and geologic work, both American and Canadian, has been done in this district and in the area adjoining it. The first and most essential preliminary requirement—that is, a topographic map—was prepared by the Canadian Boundary Commission in 1902, in connection with the accurate location of the international boundary; and in 1910 a topographic map of the Portland Canal mining area (map 50 A) was prepared by the Geological Survey of Canada. The later map covers mainly the area drained by Bear River, one of the headwater tributaries of Portland Canal. The accompanying base map (Pl. V) is compiled mainly from these two sources. A new map of this area is soon to be issued by the International Boundary Commission.

The principal publications by workers in the United States Geological Survey that have a bearing on the geology and mineralization of the Salmon-Unuk River district are as follows, named in chronologic order.

Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, 1902.

Wright, F. E., The Unuk River mining region of British Columbia: Canada Geol. Survey Summary Rept. for 1905, Ottawa, 1906.

Wright, F. E., and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, 1908.

Chapin, Theodore, Mining developments in southeastern Alaska in 1915: U. S. Geol. Survey Bull. 642, pp. 94–98, 1916.

The Skeena and Portland Canal mining divisions include that part of the Salmon-Unuk River region that lies in British Columbia. Notes on the progress of mining in these divisions have been published annually for a number of years by the British Columbia Bureau of Mines. The latest of these reports dealing with the valley of Salmon River are as follows:

Clothier, G. A., Portland Canal mining division: British Columbia Bur. Mines Ann. Rept. for 1917, pp. F68–F73, 1918.

Jack, P. S., Portland Canal mining division: Idem, p. F84.

Clothier, G. A., Portland Canal mining division: Idem for 1918, pp. K80–K83, 1919.

Investigations have also been carried on by the Geological Survey of Canada in these mining divisions, and this work is still in progress. Four reports have so far been published, and a fifth is in course of publication. The published reports are as follows:

McConnell, R. G., Portland Canal district, British Columbia: Canada Geol. Survey Summary Rept. for 1909, pp. 59–89, 1910.

McConnell, R. G., Salmon River district, British Columbia: Idem for 1911, pp. 50–56, 1912.

McConnell, R. G., Portland Canal district, British Columbia: Idem, pp. 56–71.

McConnell, R. G., Portions of Portland Canal and Skeena mining divisions, Skeena districts, British Columbia: Canada Geol. Survey Mem. 32, 1913.

The last named of these four publications is essentially a compilation from the three earlier summary reports.

The present report represents no original work whatever on the part of the writer. It is essentially a brief compilation of the work of earlier American and Canadian workers, prepared to meet the demand for a statement of the available information on the area beginning at Portland Canal and extending northwestward. The only qualification of the writer for the preparation of such a statement is a general familiarity with the country gained by geologic field work in southeastern Alaska. The latest work by the United States Geological Survey was done in the Portland Canal district by Theodore Chapin in 1915, and his report is cited above.

PHYSICAL AND ECONOMIC GEOGRAPHY.

RELIEF.

The Salmon-Unuk River region belongs in large part to the Coast Range province of southeastern Alaska and is therefore an area of considerable relief. The area included in this report extends from tidewater at Behm and Portland canals to the crest of the Coast Range and therefore lies mainly in the western half of the Coast Range. The range in this area is about 100 miles wide and has rather poorly defined crest line. Many of the peaks of the range attain elevations of 6,000 to 9,000 feet, but within this area none exceed 8,000 feet. The mountain summits are more uniform in elevation in this western portion of the range, within the area of granitic rocks, than on the east side, where argillites and greenstones occur.

Some of the larger streams in this vicinity, such as Stikine, Nass, and Skeena rivers, cut completely through the Coast Range, and the smaller streams are in general deeply incised, resulting in the development of a marked relief. Thus Unuk River at the international boundary flows at an elevation of 600 feet above sea level, and a peak a short distance northwest rises to 6,200 feet. Similarly, Salmon and Bear rivers have their upper basins adjacent to mountains of 7,000 to 8,000 feet in elevation and reach tidewater within a distance of about 15 miles.

In addition to marked relief, this area is further characterized by very precipitous slopes, caused mainly by intense glaciation. The higher peaks are sharp and serrated, owing to crest-line sapping by the glaciers. Below 5,500 feet the hills were overridden by flowing ice and the crests are smooth and rounded, but the valley walls have been oversteepened by glacial scouring and are everywhere very precipitous and in places sheer, unscalable cliffs.

DRAINAGE.

The principal streams that drain this area, named in order from northwest to southeast, are Blue, Unuk, Leduc, Chickamin, Salmon, and Bear rivers. Of these, Blue River is tributary to the Unuk and Leduc River to the Chickamin. Unuk River enters Burroughs Bay, an inlet from Behm Canal, and Chickamin River enters Behm Canal. Salmon and Bear rivers enter Portland Canal at its head. Both Unuk and Chickamin rivers rise within the Coast Range and flow through more or less canyon-like valleys in their upper courses. In their lower courses, however, the valleys of these two streams broaden out and are characterized by wide, gravel-covered bottoms. At the head of Unuk River, about 60 miles from Burroughs Bay, a narrow divide leads over to a branch of Iskoot River, through the valley of which it is possible to enter the inland plateau of British Columbia.

Salmon and Bear rivers, though shorter than the Unuk and Chickamin, are of the same general character. Salmon River heads in Salmon Glacier and flows 13 miles to Portland Canal. Its principal tributaries are Texas Creek from the west and Cascade Creek from the north. Big Missouri Ridge, on which are some of the chief mining properties of the district, lies between Cascade Creek and Salmon Glacier, and Bear River Ridge is the divide between Bear and Salmon rivers.

Bear River is a swift mountain stream about 18 miles in length that enters the upper end of Portland Canal. It heads against Strohn Creek, a tributary of Nass River, in a low pass comparable with the pass at the head of Unuk River.

GLACIERS.

The upland areas of this region are covered with snow above an elevation of about 5,000 feet, and these snow fields form the reservoir or collecting ground for numerous glaciers that extend down into the valleys. At least one-fourth of the region here described is thus covered with snow and ice. The glaciers are of the valley or alpine type, and few of them extend far down into the valley bottoms. Practically all the major streams head against the terminals of these ice lobes. This present condition of alpine glaciation is an aftermath of the greater piedmont glaciers which at an earlier period covered all the mountains of this area and formed a continuous sheet of flowing ice that extended from sea level up to an elevation of about 5,500 feet.

CLIMATE.

This region has the characteristically wet climate of the western flank of the Coast Range, though the precipitation is not so great as at some other localities in southeastern Alaska, being probably about 100 inches a year. The summer climate is cool, with considerable rainfall, and the least precipitation occurs late in the spring and early in the summer. The winter climate is comparable with that of Juneau, and the thermometer seldom falls below zero. Snow falls in the valleys from November to March. Snowslides from the steep slopes are of common occurrence late in the winter and in the spring.

TIMBER AND VEGETATION.

The region is heavily forested up to an elevation of about 3,500 feet, and stunted timber grows in places 1,000 feet higher. In the valley bottoms, where the best timber is found for mining purposes, hemlock is the most abundant as well as the most valuable tree and furnishes good timber for mining and structural uses. Sitka spruce and cottonwood are also well represented in the valleys. Balsam and mountain hemlock are more abundant on the higher slopes. In

addition to trees, a thick mantle of other vegetation, including moss and brush of several varieties, covers the bedrock exposures, except at high altitudes and on unscalable cliffs. This mantle makes prospecting difficult and accounts in part for the slow development of the mining resources.

WATER POWER.

Water powers should be available at many localities in this region, owing to the large size and steep gradients of the streams. In summer, as is the general rule in an area of high precipitation, with streams fed by melting snow and ice, water is usually plentiful. In winter, however, the supply is much less, for the precipitation is in the form of snow, and glacial melting is at a minimum. Careful measurements of the minimum run-off in winter should precede the establishment of power plants. Two power plants have already been established in Canadian territory, on Glacier and Lydden creeks, tributaries of Bear River.

SETTLEMENTS.

The two important settlements are Stewart and Hyder, the former in Canadian and the latter in American territory. Stewart, the distributing point for the Canadian part of the mining district, is at the head of Portland Canal, at the mouth of and on the west side of Bear River. It had a population of about 250 people in the fall of 1919. Hyder, the American distributing point, is about 2 miles from Stewart, at the mouth of and on the east side of Salmon River. In the fall of 1919 it was said to consist of 30 to 40 houses and was supplied with a wharf.

MEANS OF COMMUNICATION.

Hyder and Stewart, being on tidewater, are connected by steamship and gas-boat service with Prince Rupert and Ketchikan. A railroad starting from Stewart has been built up Bear River for a distance of about 12 miles, and a wagon road has also been constructed up the Bear River valley. Another wagon road has been built up the east side of Salmon River from Hyder for 11 miles, and a trail continues up onto the ridge between Salmon Glacier and Cascade Creek as far as the Big Missouri mine, a distance from Hyder of about 20 miles. A good wagon road has been built from Elevenmile up to the Premier mine, a distance of 5 miles. Another good road connecting Stewart and Hyder is nearing completion. During the summer of 1920 a road will probably be built from Elevenmile up Big Missouri Ridge. The Salmon River road is the only feasible means of egress from the Canadian mining properties along the west side of Bear River and on Big Missouri Ridge.

Another means of entrance to this region is by way of Unuk River. In 1905 a wagon road was built up Unuk River for a dis-

tance of 42 miles to a mining prospect, but portions of the road are now washed out.

GEOLOGY.

SALIENT FEATURES.

Little geologic work has been done in the American part of the Salmon-Unuk River region, chiefly because the rocks are mainly intrusive and afford little information regarding the geologic history of the region. On the Canadian side, however, a considerable amount of geologic study and mapping has been accomplished, chiefly by R. G. McConnell, of the Geological Survey of Canada, whose reports are listed on page 130. Subsequent work has been done by J. J. O'Neill, of the same organization, but the results of his investigations have not yet been published. The writer has merely compiled a condensed summary of the geology, so far as known at present.

The Coast Range batholith of granitic rocks is bordered on the east in the vicinity of Portland Canal by two series of sedimentary rocks, mainly of argillaceous character, between which lies a volcanic complex of massive and fragmental igneous rocks, usually of greenstone habit. All three of these formations are cut by intrusive rocks. At some localities Tertiary lavas are also present. Overlying the hard rocks are surficial deposits of alluvial, estuarine, and glacial origin. These six rock units, named in order from oldest to youngest, are the Bitter Creek formation, the Bear River formation, the Nass formation, the granitic rocks of the Coast Range, the Tertiary lavas, and the surficial deposits. The Bear River formation is a complex of volcanic rocks, in which has occurred the mineralization on Bear River and Big Missouri ridges, where mining developments are now progressing so rapidly.

BITTER CREEK FORMATION.

In the vicinity of Portland Canal the Bitter Creek formation is not known to occur west of Bear River, and therefore it will probably not be seen along the international boundary, where present mining interest centers. The formation consists mainly of argillite, which in places has developed a slaty cleavage, usually parallel with the original bedding planes. Some beds of much altered greenstone of tuffaceous origin and small nonpersistent beds of crystalline limestone are interstratified with the argillite at certain localities. This series of rocks as exposed east of Bear River dips southwestward under the other formations and is considered older. These rocks are either Paleozoic or Mesozoic; their exact age is not known. In the valleys of Glacier and Bitter creeks, eastern tributaries of Bear River, quartz veins and other mineralized zones are present in the Bitter Creek formation.

The upper 25 or 30 miles of Unuk River drains a schist-argillite belt, which begins about 4 miles upstream from the international boundary and is probably, at least in part, the equivalent of the Bitter Creek formation as known east of Bear River. It is likely that the schistose members in this belt have been developed by dynamic metamorphism caused by the intrusion of the Coast Range batholith. This belt of argillite appears to parallel the granite of the east from British Columbia to Skagway, and is characterized along its whole extent by the occurrence here and there of silver and gold bearing veins in the vicinity of the granitic rocks. Placer gold and lode deposits of silver, gold, and lead have been found in the upper valley of Unuk River, on the Canadian side of the boundary.

At least two narrow bands of schist cross Unuk River below the international boundary, and a somewhat wider band follows along the east side of Behm Canal. These schistose rocks are believed to represent metamorphosed phases of the sedimentary series of rocks east of the Coast Range batholith.

BEAR RIVER FORMATION.

Overlying the Bitter Creek formation is the Bear River formation, which crops out along the east side of Salmon River in Alaska and continues northeastward into British Columbia. This formation is the main country rock of the Salmon River valley, where a number of promising mining properties are situated. It is a complex made up chiefly of massive and tuffaceous volcanic rocks. The massive rocks are in general of andesitic nature and are called porphyrites. In general they are porphyritic, though this feature is not noticeable in all hand specimens, and they show a flow structure in many thin sections. Plagioclase feldspar in two generations is the chief constituent and is accompanied by subordinate amounts of augite or hornblende, iron oxides, and apatite. Secondary minerals, including chlorite, calcite, epidote, leucoxene, and hematite, are sufficiently common to impart to the rocks as a whole a greenstone habit. The fragmental rocks consist of tuff, volcanic breccias, and agglomerates and evidently indicate that sedimentation played a considerable part in the formation of this complex. This inference is further borne out by the presence of some thin intercalated beds of argillite.

Along the east side of Salmon Creek, in American territory, where this series of rocks abuts against the granite of the Coast Range, the greenstones are intensely sheared and metamorphosed and have developed into coarse greenish and grayish schists, in which the schistosity roughly parallels the greenstone-granite contact. The rocks dip steeply toward the granite, and in general the metamorphism increases in intensity in that direction.

NASS FORMATION.

Little need be said of the group of rocks that constitute the Nass formation, for they are not known to occur in Alaska and have not been found to be mineralized. Like the Bitter Creek formation, the Nass consists of a thick series of argillite, with some coarse clastic beds. In the upper Salmon River valley, within British Columbia, isolated bodies of such rocks overlie the Bear River formation.

GRANITIC ROCKS OF THE COAST RANGE.

The intrusive rocks that compose the Coast Range batholith range from granite to diorite and even to gabbro. Quartz-hornblende diorite, however, is the predominating type. The major part of the Salmon-Unuk River region is occupied by granitic rocks.

Within the central part of the granitic batholith the granite is of rather uniform texture, but at the edges, particularly along the west flank, variations are seen. Thus along the shores of Behm Canal pegmatite and aplite dikes form an intricate network of white strands at the edge of the granodiorite, and in the adjacent schist several generations of such dikes may be observed. At a distance this complex of granodiorite, schist, and dikes resembles a breccia. The granodiorite is also commonly gneissoid, and the included fragments of schist merge into rocks resembling basic differentiation products. As a result of this condition, brought about by intrusion at great depth, the contact between the granite and other country rock is indistinct in many places along the western flank of the batholith. This condition is less apparent along the eastern flank, although dike rocks are also present there.

The typical quartz-hornblende diorite of the Coast Range is composed essentially of plagioclase, feldspar, quartz, biotite, hornblende, and orthoclase, named in the order of abundance. Titanite, magnetite, and apatite are accessory minerals, and small amounts of secondary products such as epidote, sericite, calcite, and chlorite also occur in the central part of the batholith.

These granitic rocks are the source of the mineralizing solutions that have produced the ore deposits in this district, but the methods of formation of the deposits have been devious, and the resulting ores show wide differences in location, character, extent, and mineral content. It is noticeable, however, that important mineralization does not appear to have occurred within the main batholith but was confined to the edges of the granitic rocks and the adjacent sedimentary rocks. This is due to the fact that the mineralizing solutions found their easiest upward course along the fractured zones near the contact. The practical importance of this generalization is that the best hope of finding ore deposits on the American side of the Unuk-

Salmon River district is along the east side of Salmon River, where the Bear River formation occurs.

TERTIARY BASALT.

The Tertiary basalts of this region are gray-green to black porphyritic rocks ranging in composition from basic andesite to normal basalt, composed essentially of plagioclase, pyroxene, and magnetite, with a little olivine or quartz. Some alteration has taken place, but as a rule these rocks are very fresh in appearance. These beds of lava have been little disturbed since their formation and in most places lie almost horizontal. Some tuffaceous layers are interbedded with the lavas. Postglacial basaltic lavas are found in the lower valley of Blue River, just above its junction with the Unuk.

SURFICIAL DEPOSITS.

The surficial deposits are chiefly of three types, glacial, estuarine, and alluvial. The glacial deposits consist of till, glaciofluviatile material, and boulder clay, collected in deposits of many types. Estuarine deposits similar to those now being formed in the heads of the fiords are found on the hillsides at a height of 350 to 500 feet above the present sea level and point unmistakably to a postglacial uplift. Alluvial deposits composed of silt, sand, and gravel occur in the valleys and are due to aggradation by the present streams. Lacustrine deposits are also present in small areas.

MINERAL RESOURCES.

GENERAL LOCATION.

The mineralized zone of the Salmon-Unuk River region lies mainly along the east flank of the Coast Range granite batholith and is therefore largely in Canadian territory, except in the valley of Salmon River, at the head of Portland Canal. Prospecting and mining have been done at two general localities, one around the headwaters of Unuk River and the other at the head of Portland Canal, in the valleys of Salmon and Bear rivers. A zone of mineralization, however, lies along the east side of the granite batholith in British Columbia, and it is very likely that other mineral deposits will be found along this zone. It is significant that mineral deposits have been found at both the localities mentioned, which, as before pointed out, are the two natural passages through the range from the west in this particular district. The Portland Canal area is the more advantageously situated, for Portland Canal cuts completely through the granite and brings tidewater almost to the mines. The renewal of interest in mining in this district is due to the successful development of the Premier mine, and other properties of similar character

in the upper valley of Salmon Creek. Most of these properties are on the Canadian side of the boundary, but it is not unlikely that others worth while will ultimately be located on the American side.

UNUK RIVER.

Placer gold was reported in the Canadian part of the Unuk Valley during the Cassiar excitement in the early seventies but received little attention. In the early eighties gold-bearing gravels were discovered on Sulphide Creek, and some placer gold was mined. Subsequent to the rush of 1898 lode deposits were located on Sulphide, Canon, and Bowlder creeks, tributaries of Unuk River, and on the North and South forks of the Unuk. On Sulphide Creek two quartz veins in particular were prospected—one a 2 to 8 inch vein of high-grade ore and the other a 20 to 30 foot vein of lower-grade ore. The high-grade ore from the narrow vein consisted chiefly of tetrahedrite (gray copper), pyrite, sphalerite, galena, and native silver. About 100 tons of ore from this vein was milled in a small stamp mill in 1901 and is reported to have given high assay returns, particularly in silver. The ore minerals of the other vein consisted of pyrite, galena, sphalerite, and chalcopyrite, with a little native gold in the oxidized parts of the vein. The remoteness of these lodes from the coast and the difficulties of access, even after a road was built up Unuk River, have caused a loss of interest in this mineralized area, and of late years no work has been done in this vicinity. It is admitted that a low-grade property would be of little value at that distance from the coast, but further prospecting along the east side of the granite batholith, north and south from Unuk River, with the purpose of locating lodes of high-grade ore, might be well worth while.

SALMON RIVER.

GEOGRAPHY.

Salmon and Bear rivers, at the head of Portland Canal, particularly the former, are the centers of the present mining interest in this district. Bear River flows entirely in British Columbia, but Salmon River lies partly in British Columbia and partly in Alaska. On this account, and because interest centers in this locality, only the conditions in the valley of Salmon River will be discussed here.

Salmon River rises in Salmon Glacier and flows about 13 miles to Portland Canal about 2 miles below Stewart. All of Salmon River proper lies in Alaska. Cascade and Texas creeks are the two important headwater tributaries. Cascade Creek rises in British Columbia and flows about 6 miles southward to join Salmon River about 2 miles below the glacier. Texas Creek lies entirely in Alaska,

is about 10 miles in length, and flows in a general easterly direction to Salmon River about 4 miles below the glacier. The main ridge between Salmon and Bear rivers is known as Bear River Ridge, and the smaller ridge lying between Salmon Glacier and Cascade Creek is called Big Missouri Ridge. (See Pl. V.) The properties now under intensive development lie in the valley of Salmon River along the west side of Bear River Ridge and on Big Missouri Ridge.

AREAL GEOLOGY.

The country rock along the east side of Salmon River and Salmon River Glacier is mainly the andesitic greenstone of the Bear River formation. To the west lies the granite of the Coast Range. The contact between these two formations, however, is irregular and is marked by Salmon River only in the most general way. Isolated areas of granodiorite are present in the Bear River formation east of Salmon River and in fact are the immediate sites of a number of the ore deposits.

The greenstone near the granitic rocks is sheared and at places rendered schistose, the schistosity trending north and dipping toward the granite. The shearing and fissuring that are related to the ore deposition, however, cut transversely across the earlier structure, as may be seen at the Premier mine. Dike rocks of a variety of types, ranging from granite to more basic rocks, together with other intrusives of similar composition but of a fine-grained porphyritic character, are found in the Bear River formation. Some of these dikes are connected with the intrusion of the Coast Range batholith; others are no doubt more closely related to the andesitic greenstone sequence. It is presumed that the mineralization is connected with the intrusive igneous rocks of the Coast Range.

TYPES OF DEPOSITS.

Two general types of lode deposits may be found along the east side of the Coast Range batholith, within the Salmon–Unuk River region. These may be designated vein deposits and replacement deposits. The vein deposits consist of metallic minerals, usually with quartz, which have been laid down in open fractures, with a minimum of replacement of the country rocks. Where such deposits fill openings of regular form, such as openings along fault or joint planes, true veins are developed. Where the infiltration and deposition have occurred in irregularly fractured areas, something akin to a brecciated ore zone results. The replacement deposits are those which have been formed in zones of shearing and fissuring, with or without gangue minerals but accompanied by much replacement of the country rock. Naturally these two types are not mutually

exclusive, and both types may be found in close association at some localities. It appears that the lodes along the east side of the Coast Range have been deposited at shallower depth than those along the west side, as at Juneau, and in contradistinction to the lodes of Kasaan Peninsula they show little or no evidence of contact-metamorphic origin.

Deposits of both the types mentioned are found in the Salmon River valley. The low-grade ores are chiefly impregnation and replacement deposits of considerable size lying along zones of fissuring and shearing. They are characterized by indistinct rather than sharp boundaries. The ore minerals are usually pyrite, sphalerite, galena, and chalcopyrite, and the valuable constituents are gold, silver, zinc, and to a smaller extent copper. Pyrrhotite is present at some localities, but it carries little gold, as the gold is apparently associated for the most part with pyrite. At and in the vicinity of these impregnated zones the country rock is much silicified and altered to calcite, chlorite, and sericite. In places the gangue material consists solely of such altered country rock. Considerable oxidation has taken place, as is indicated by the discoloration at the surface outcrops, and there is reason for the belief that downward enrichment may have played some part in the formation of some of the lodes.

The high-grade deposits are essentially rich silver and gold ores, occurring both as veins and as replacement deposits, many of them within zones of lower-grade ores. These higher-grade ores have not been studied in detail, and their exact relation to the lower-grade ores is not definitely understood, though the evidence available points to their formation at a somewhat later period. The silver minerals present in the high-grade ores include argentite (silver glance), argentiferous tetrahedrite, native silver, pyrargyrite, and proustite, and possibly stephanite and other silver minerals. Little native gold is seen, and ores with high gold content are characterized by much pyrite.

LODE PROPERTIES.

The properties at present being prospected or developed include the Premier, Mineral Hill, Big Missouri, Bush mines, Forty-Nine, Indian mines, International, Payroll, Yellowstone, Boundary, Northern Light, Cascade Forks, Spider, Hercules, Silver Tip, Bunting, Unicorn, Lake & O'Leary, New Alaska, Knobhill, and other groups of claims. All these are in British Columbia. The International, Premier, Bunting, and Bush mines properties lie along the west flank of Bear River Ridge, but the Indian, Boundary, Payroll, Mineral Hill, Big Missouri, Hercules, Forty-Nine, and Yellowstone groups of claims stretch northward up Big Missouri Ridge.

The Premier mine is at present considered the most promising of these properties. A description of the history and development of

this mine is given by Charles Bunting.[1] This property, which originally consisted of two claims, lies along the west side of Bear River Ridge and was discovered and staked in June, 1910. These and adjoining claims later passed into the hands of O. B. Bush, who organized the Salmon-Bear River Mining Co. This company and others to which the property was successively bonded carried on development work until the spring of 1919, when the potentialities of the property were finally recognized and demonstrated by R. K. Neill, of Spokane. Partial ownership and financial control have now passed into the hands of the American Smelting & Refining Co.

The lode is reported to consist of three low-grade ore bodies and one of high grade, which appear to be of the replacement type above described. The country rock is the Bear River formation, or andesitic greenstone, greatly sheared, fissured, and fractured. The high-grade deposit, on which the most work has been done, is an ore zone in the fractured porphyry and follows a shear zone of fissuring and fracturing which strikes N. 80° E. and dips 60° S. The gangue is chiefly the silicified country rock. The ore minerals are reported to be argentite (silver glance), argentiferous tetrahedrite, stephanite (brittle silver), pyrargyrite, proustite, native silver, and pyrite carrying much gold. A little pyrrhotite is present, but it carries only a small percentage of gold. Small stringers in the larger ore body are reported to carry wonderful specimens of the silver minerals. Though classed as a rich silver mine, the ore is valuable for both gold and silver, the latter predominating. A sampling of all the present workings and openings is reported by Bunting to have given an average value well over $30 a ton in silver and gold. The 512 tons that has so far been shipped gave smelter returns of $168,000.

Less is known as yet of the possibilities of the low-grade deposits on the Premier property, but it is assumed that like other low-grade deposits near by, they consist of silicified zones in the andesitic greenstone, impregnated with sulphides, chiefly pyrite, galena, sphalerite, and chalcopyrite, carrying both gold and silver.

The big Missouri, Mineral Hill, and Bush properties are also being developed.

With regard to mining properties in the Alaska portion of the Salmon River valley the following notes by Chapin[2] give some idea of what had been accomplished up to 1915:

> A group of claims extending from Sevenmile, on Salmon River, to Fish Creek, has been located, but only two of them have been developed. On the Riverside claim a tunnel 100 feet above the river flat has been driven for 140 feet along a strong fissure vein. The vein averages about 4 feet in width but pinches to 18 inches and in places widens to 6 feet. Both walls are well defined. The wall rock is somewhat

[1] Bunting, Charles, The Premier gold mine, Portland Canal, British Columbia: Min. and Sci. Press, Nov. 8, 1919, pp. 670–672.

[2] Chapin, Theodore, Mining developments in southeastern Alaska, 1915: U. S. Geol. Survey Bull. 642, pp. 97–98, 1916.

altered but contains little gouge. The vein filling is quartz with abundant sulphides. Pyrite is the most abundant along the hanging wall and occurs in solid bunches and in disseminated particles associated with chalcopyrite. On the footwall galena is the most plentiful sulphide. The country rock is crystalline schist. On a parallel lode of much the same character the Riverview claim is being developed. The vein strikes N. 60° W. and dips about 60° NE. An adit has been driven for 17 feet, exposing a vein that varies from 1 foot to 4 feet in width. At the mouth of the opening it is 2 feet wide on the roof and widens to 4 feet on the floor of the adit. At the face it is from 12 to 18 inches in width. Although the vein swells and narrows from place to place, the walls are well defined.

At Elevenmile a little prospecting has been done, and several claims have been located. On the Elevenmile and Iron claims a number of open pits have exposed an iron-stained lode that follows a brecciated zone filled with veins of quartz carrying chalcopyrite, sphalerite, and galena. Stringers of sulphide form shoots of very rich ore with high silver content. On the Iron claim a ton of this high-grade ore has been sacked ready for shipment. The lode strikes northeast and dips steeply northwest. On the hillside above Elevenmile, at an altitude of 1,500 feet, the Bertha and Western claims are being developed on a northeastward-trending lode. One surface cut shows the lode to be at least 15 feet in width. It consists of silicified schistose green tuff of the "Bear River formation," with disseminated pyrite, chalcopyrite, galena, and sphalerite. A number of claims have been staked on a zone of disseminated deposits exposed along Salmon River at Eightmile and Ninemile, but only a little work has been done.

Some promising fissure lodes have been located by Murphy & Stevenson on Fish Creek and its tributary, Skookum Creek, where more than the necessary amount of assessment work has been done. Near the mouth of Skookum Creek an adit was driven for 25 feet along a fissure that had been traced by surface trenches for 2,000 feet The vein is 4½ feet wide, strikes N. 40° E., and dips about 55° SE. The quartz gangue carries galena, chalcopyrite, tetrahedrite, sphalerite, and pyrite in veinlets and irregular patches. It is being exploited mainly for its gold and silver content.

Near the head of Skookum Creek, at an altitude of 1,600 feet, a fissure vein has been opened by an adit 320 feet in length and several crosscuts and inclines. The gangue is quartz. Metallic sulphides present are tetrahedrite, chalcopyrite, galena, sphalerite, and pyrite in blebs and veinlets penetrating the quartz, and the richest ore occurs in veinlets of tetrahedrite and galena. The country rock is porphyry and schistose tuff of the "Bear River formation." The lode strikes N. 55° W. and dips 45° SW. At the portal it is about 18 inches wide. At 70 feet from the portal only a part of the vein is exposed, as the ore has been removed to a wall within the vein. At this place the vein is 3 feet wide plus an unknown width in the wall of the adit. At various places portions of the vein said to be very rich have been stoped out. At 300 feet from the adit mouth the lode is abruptly cut by a vertical fault trending nearly perpendicular to the lode, and short drifts along the fault plane in both directions had not shown the position of the faulted lode. Samples of ore said to come from a near-by prospect, which was not visited, contain particles of free gold in siliceous gangue.

Several claims have been staked on Texas Creek. The ore bodies are reported to be quartz veins carrying seams of tetrahedrite penetrating granite and pegmatite. Little work has been done in this locality.

WATER-POWER INVESTIGATIONS IN SOUTHEASTERN ALASKA.[1]

By George H. Canfield.

INTRODUCTION.

Systematic investigation of the water resources of Alaska was begun by the United States Geological Survey in 1906 and has been carried on in different parts of the Territory to the present time. This investigation was undertaken in response to the need for definite information in regard to water available for many uses, among which the most important are hydraulicking, dredging, and supplying power for mines, canneries, and sawmills.

The investigation of the water resources of southeastern Alaska was begun by the Geological Survey in cooperation with the Forest Service in 1915 and was designed to determine both the location and the possibilities of water-power sites. The results of previous years' work have already been published.[2] A table showing water-power possibilities in southeastern Alaska is given on page 184.

The Geological Survey maintained a number of gaging stations in southeastern Alaska throughout the year, and other stations were installed in cooperation with individuals and corporations. The records obtained at these stations are contained in this paper. Acknowledgment is made to those who have assisted in this work, particularly to Mr. W. G. Weigle and Mr. Charles H. Flory, supervisors of the Forest Service at Ketchikan, and to Mr. Philip H. Dater, district engineer at Portland, Oreg.

The stations for which the records are presented are the following:

Myrtle Creek at Niblack.
Ketchikan Creek at Ketchikan.
Fish Creek near Sealevel.
Swan Lake outlet at Carroll Inlet.
Orchard Lake outlet at Shrimp Bay.
Shelockum Lake outlet at Bailey Bay.
Karta River at Karta Bay.
Cascade Creek at Thomas Bay.
Green Lake outlet at Silver Bay.

[1] In cooperation with the United States Forest Service.
[2] U. S. Geol. Survey Bull. 662, pp. 100-154, 1918; Bull. 692, pp. 43-83, 1919.

Baranof Lake outlet at Baranof.
Sweetheart Falls Creek near Snettisham.
Crater Lake outlet at Speel River, Port Snettisham.
Long River below Second Lake, at Port Snettisham.
Grindstone Creek at Taku Inlet.
Carlson Creek at Sunny Cove.
Sheep Creek near Thane.
Gold Creek at Juneau.
Falls Creek at Nickel.
Porcupine Creek near Nickel.

STATION RECORDS.

MYRTLE CREEK AT NIBLACK, PRINCE OF WALES ISLAND.

LOCATION.—Halfway between beach and Myrtle Lake outlet, which is one-third mile from tidewater, 1 mile from Niblack, in north arm of Moira Sound, Prince of Wales Island, and 35 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—July 30, 1917, to December 31, 1919.

GAGE.—Stevens continuous water-stage recorder on right bank; reached by a trail which leaves beach near the mouth of the creek.

DISCHARGE MEASUREMENTS.—At medium and high stages made from a cable across creek at outlet of lake; at low stages made by wading.

CHANNEL AND CONTROL.—The gage is in a pool 10 feet upstream from a contracted portion of the channel, at a rocky riffle that forms a well-defined and permanent control. At the cable section the bed is smooth, the water deep, and the current uniform and sluggish.

EXTREMES OF DISCHARGE.—Maximum stage during year from water-stage recorder, 3.07 feet at 9 a. m. December 18 (discharge, 196 second-feet); minimum stage 1.08 feet, September 8–9 (discharge, 28 second-feet).

1917–1919: Maximum stage recorded, 4.40 feet at 5 p. m. November 18, 1917; discharge, estimated from extension of rating curve, 387 second-feet; minimum stage, 1.08 feet September 8–9, 1919 (discharge, 28 second-feet).

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve, determined by five discharge measurements, is very well defined between 30 and 220 second-feet. Operation of water-stage recorder satisfactory except for periods shown in footnote to daily-discharge table. Daily discharge ascertained for periods recorder was operating by applying to rating table mean daily gage height; for periods recorder was not operating by determining with a planimeter the monthly means from an estimated hydrograph drawn by means of staff gage readings by observer about once every 10 days, maximum and minimum stages indicated by the recorder, and recorded hydrograph, and by comparison of the record for this station with that for Karta River. Records good except for periods when the recorder stopped, for which they are fair.

Myrtle Lake, the outlet of which is 800 feet from Niblack Anchorage, is 95 feet above sea level and covers 122 acres. Niblack Lake, the outlet of which is 5,700 feet from Niblack Anchorage, is 450 feet above sea level and covers 383 acres. Mary Lake, unsurveyed, is about 600 feet above sea level and is a mile long and one-fourth to one-half mile wide. The large lake area in this small drainage basin is the cause of the well-maintained flow during the winter and periods of little rainfall.

The following discharge measurement was made by G. H. Canfield:

August 29, 1919: Gage height, 1.20 feet; discharge, 32 second-feet.

Daily discharge, in second-feet, of Myrtle Creek at Niblack for 1919.

Day.	Jan.	Feb.	Mar.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	79	....	44	....	49	39	31	33	50	48
2	96	....	42	....	48	39	30	33	46	46
3	99	....	42	....	48	39	29	34	....	45
4	157	56	43	....	52	38	29	33	....	44
5	134	52	44	....	51	37	29	33	....	43
6	146	52	43	....	49	37	30	35	....	42
7	200	51	42	....	50	36	29	46	....	42
8	213	63	41	....	72	36	29	40	....	41
9	220	77	41	....	67	35	28	37	....	40
10	220	100	39	....	58	35	28	56	....	39
11	194	84	38	....	58	34	29	54	....	38
12	175	73	38	....	78	34	35	50	....	36
13	194	79	37	....	82	35	44	47	....	36
14	163	73	37	....	85	35	38	46	57	36
15	140	68	36	....	75	39	34	....	63	42
16	127	88	35	....	68	50	32	....	64	76
17	112	91	35	....	64	45	58	....	88	105
18	105	100	34	....	60	40	77	....	94	175
19	92	100	....	....	57	44	76	50	77	125
20	84	85	....	....	55	64	58	48	118	92
21	....	73	....	....	52	52	60	....	102	79
22	....	66	....	....	51	45	63	....	84	116
23	....	60	....	....	49	39	53	....	88	134
24	....	57	....	....	48	36	46	....	73	120
25	....	54	....	....	47	35	44	33	64	....
26	....	52	....	....	45	34	40	....	58	....
27	....	48	....	55	44	33	38	....	58	....
28	....	47	....	53	43	33	36	....	56	....
29	....	....	....	52	42	33	35	....	53	....
30	....	....	....	50	41	33	35	47	50	....
31	....	....	....	....	41	32	....	53	....	....

NOTE.—Discharge for following periods estimated because of unsatisfactory operation of water-stage recorder, from maximum and minimum stages indicated by recorder and by comparison with hydrograph for Karta River: Jan. 21–31, 80 second-feet; Feb. 1–3, 65 second-feet; Mar. 19–31, 60 second-feet; Apr. 1–31, 100 second-feet; May 1–31, 110 second-feet; June 1–26, 90 second-feet; Dec. 25–31, 115 second-feet. Discharge for following periods estimated from records for Karta River: Oct. 15–18, 40 second-feet; Oct. 21–24, 35 second-feet; Oct. 26–29, 35 second-feet; Nov. 3–13, 40 second-feet.

Monthly discharge of Myrtle Creek at Niblack for 1919.

Month.	Discharge in second-feet.			Run-off (in acre-feet).
	Maximum.	Minimum.	Mean.	
January	220	....	124	7,620
February	100	47	69.4	3,850
March	61	34	48.1	2,960
April	....	....	100	5,950
May	....	....	110	6,760
June	....	50	85.0	5,060
July	85	41	55.8	3,430
August	64	32	38.6	2,370
September	77	28	40.8	2,430
October	56	33	40.3	2,480
November	118	....	59.4	3,530
December	175	36	78.9	4,850
The year	220	28	70.8	51,300

KETCHIKAN CREEK AT KETCHIKAN.

Location.—One-fourth mile below power house of Citizens Light, Power & Water Co. one-third mile northeast of Ketchikan post office, downstream 200 feet from mouth of Schoenbar Creek (entering from right), 1¼ miles from mouth of Granite Basin Creek (entering from left), and 1½ miles from outlet of Ketchikan Lake.

Drainage area.—Not measured.

Records available.—November 1, 1909, to June 30, 1912; June 9, 1915, to December 17, 1919.

Gage.—Vertical staff fastened to a telephone pole near board walk on left bank at bend of creek 200 feet downstream from mouth of Schoenbar Creek; read by employee of the Citizens Light, Power & Water Co. The gage used since June 9, 1915, consisted of the standard United States Geological Survey enameled gage section graduated in hundredths, half-tenths, and tenths from zero to 10 feet. The original gage, established November, 1909, and read until June 30, 1912, is at same location and same datum. It is a staff with graduations painted every tenth. Gage not replaced when a new telephone pole was placed December 17, 1919, by the company.

Discharge measurements.—At medium and high stages from footbridge about 500 feet upstream from gage; measuring section poor, as the bridge makes an angle of 20° with the current, and at high stages the flow is broken by large stumps near left bank and at middle of bridge. Low-stage measurements made by wading 50 feet below bridge or at another section 100 feet above gage. The flow of Schoenbar Creek has been added to obtain total flow past gage.

Channel and control.—Gage is located in a large deep pool of still water at a bend in creek. The bed of the stream at the outlet of this pool is a solid rock ledge, but changes in a gravel bar at lower right side of pool cause occasional changes in stage-discharge relation.

Extremes of discharge.—1909–1912 and 1915–1919: Maximum stage recorded, 8.3 feet November 18, 1917 (discharge estimated from extension of rating curve, 4,400 second-feet); minimum discharge, 34 second-feet, September 24, 1915.

Ice.—Ice forms along banks but control remains open.

Diversions.—A small quantity of water is diverted above the station for the use of the town of Ketchikan, the New England Fish Co., and the Standard Oil Co.

Regulation.—Small timber dam and headgates are located at outlet of Ketchikan Lake. Water diverted through power house is returned to creek above gage but causes very little diurnal fluctuation. During low water the flow is increased by water from the reservoir.

Accuracy.—Stage-discharge relation changed during high water August 19, 1917. Rating curve used August 19, 1917, to December 17, 1919, fairly well defined below and poorly defined above 800 second-feet. Gage read to hundredths once daily. Daily discharge ascertained by applying gage height to rating table.

The following discharge measurement was made by G. H. Canfield:

February 27, 1919: Gage height, 0.18 foot; discharge, 49 second-feet.

Daily discharge, in second-feet, of Ketchikan Creek at Ketchikan for 1917–1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1917.												
1	118	61	54	42	125	228	720	180	110	180	2,370	95
2	69	54	54	42	93	196	382	200	110	450	1,778	83
3	71	54	61	245	90	196	498	160	95	466	450	72
4	66	108	66	241	74	196	720	180	95	295	295	55
5	64	176	69	125	76	220	616	160	95	1,150	230	67
6	74	249	66	99	160	308	357	160	95	410	1,530	80
7	142	232	61	82	160	216	382	160	89	230	3,930	160
8	262	285	54	79	523	436	285	160	80	160	1,200	570
9	87	212	50	76	285	262	180	142	80	144	450	160
10	262	216	50	76	220	196	160	241	80	125	700	95
11	276	168	52	71	216	200	160	142	95	295	490	67
12	115	125	54	76	220	204	142	125	104	230	370	55
13	82	523	52	76	212	204	142	108	110	180	2,950	55
14	79	450	48	64	200	204	142	160	140	160	4,000	55
15	74	740	44	64	180	204	142	285	205	180	1,350	55
16	64	377	44	64	180	196	139	241	225	180	490	55
17	66	180	66	66	180	204	139	332	160	180	1,250	55
18	66	118	61	90	285	553	142	1,290	180	180	4,400	55
19	85	108	54	142	220	493	142	31,60	140	160	2,310	53
20	74	69	61	176	200	332	125	1,530	110	295	950	53
21	61	66	54	142	180	382	125	530	110	330	530	51
22	64	66	71	139	172	357	125	1,890	110	750	230	45
23	102	64	69	142	160	220	125	450	107	700	230	45
24	142	64	56	142	176	220	285	260	107	260	450	45
25	204	61	54	142	180	180	155	205	205	230	490	45
26	125	61	54	142	176	180	125	200	119	260	370	45
27	122	64	44	142	180	180	180	295	205	230	750	43
28	90	54	44	139	190	160	142	530	295	410	295	45
29	66	....	46	142	216	160	142	230	378	260	160	210
30	64	....	44	139	220	190	142	205	354	900	116	260
31	61	....	42	....	220	....	180	195	....	2,490	....	230
1918.												
1	205	60	55	55	144	152	180	140	77	67	800	850
2	630	55	55	60	316	125	164	134	75	95	370	700
3	260	450	53	75	410	125	148	110	67	152	140	470
4	570	230	45	80	410	122	125	67	67	1,590	116	122
5	230	148	45	62	370	95	125	104	65	1,530	180	80
6	180	119	43	53	390	86	128	62	62	470	650	53
7	125	116	43	60	370	75	131	570	55	309	390	116
8	45	95	43	89	260	67	125	510	55	800	288	104
9	45	134	43	180	242	60	119	450	53	370	160	86
10	55	119	43	92	230	110	125	330	67	323	122	67
11	86	110	43	110	220	160	95	180	65	1,770	80	64
12	89	80	43	110	205	168	119	160	55	490	134	52
13	86	67	45	119	206	180	95	80	55	330	288	58
14	65	60	45	125	172	205	89	72	53	316	225	263
15	89	55	45	134	160	205	101	75	45	230	122	230
16	83	53	45	125	180	200	86	89	53	248	134	230
17	230	53	45	119	205	200	80	92	260	610	92	281
18	309	51	45	260	205	172	80	89	205	205	67	295
19	144	45	45	402	215	160	80	·122	67	370	65	230
20	110	45	45	330	225	160	77	260	53	725	67	110
21	89	45	80	316	230	156	75	205	53	312	410	104
22	254	45	53	323	160	152	75	675	53	140	230	92
23	260	45	55	260	148	152	75	510	95	119	248	160
24	274	45	75	160	125	152	72	295	65	122	370	134
25	131	43	77	152	122	160	92	205	260	92	410	610
26	110	43	67	148	110	172	104	190	125	900	370	1,000
27	119	45	75	131	110	160	530	650	62	390	288	260
28	101	67	80	131	330	125	530	288	55	370	750	125
29	80	....	89	140	205	125	200	295	55	281	1,950	101
30	60	....	62	172	200	152	148	137	53	330	1,200	67
31	55	....	55	....	176	....	180	125	....	825	....	55

Daily discharge in second-feet, of Ketchikan Creek at Ketchikan for 1917–1919.—Contd.

Day	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1919.												
1	80	67	55	950	152	205	144	89	67	67	370	65
2	410	60	53	700	122	200	125	80	67	62	230	62
3	260	55	55	390	110	180	116	80	65	77	140	67
4	1,000	55	53	260	104	172	148	77	65	80	67	55
5	610	67	53	248	92	160	110	77	67	80	67	62
6	410	55	53	180	83	160	101	75	65	410	65	67
7	630	60	51	168	80	152	95	77	62	110	62	62
8	950	205	53	370	119	140	110	80	62	101	92	60
9	610	168	55	110	125	140	107	77	60	160	80	62
10	370	140	60	92	140	152	116	77	67	80	67	60
11	370	125	55	140	160	160	118	80	67	205	89	62
12	230	119	53	92	180	152	110	83	89	125	450	60
13	140	110	53	92	160	131	230	168	67	110	370	62
14	119	86	53	95	295	134	370	172	67	101	370	67
15	104	67	55	89	610	134	260	610	65	89	570	230
16	86	116	53	95	530	128	152	172	67	122	1,100	700
17	67	110	53	89	230	125	390	110	1,650	77	1,590	630
18	67	230	53	95	470	125	110	101	1,100	67	1,410	......
19	65	110	53	95	725	152	116	134	750	72	1,350	......
20	62	75	62	370	610	248	107	725	570	75	1,150	......
21	67	72	83	323	281	267	113	205	1,100	75	750	......
22	110	67	95	570	180	458	98	125	800	67	570	......
23	101	65	89	295	195	570	110	101	205	67	390	......
24	80	62	86	220	248	394	95	95	180	65	230	......
25	72	62	53	172	260	180	101	80	134	65	125	......
26	80	60	53	650	281	205	98	70	110	72	116	......
27	80	55	62	750	230	180	98	75	89	80	95	......
28	74	55	86	634	220	160	104	75	80	72	67	......
29	180	......	195	295	140	152	101	72	67	67	67	......
30	110	......	650	180	122	140	107	67	67	225	67	......
31	75	......	530	......	116	......	95	80	......	205	......	......

Monthly discharge of Ketchikan Creek at Ketchikan for 1917–1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1917.				
January	267	61	106	6,520
February	710	54	179	9,940
March	71	42	54.8	3,370
April	245	42	114	6,780
May	573	74	192	11,800
June	553	160	249	14,800
July	720	125	240	14,900
August	3,160	108	455	28,000
September	378	80	146	8,690
October	2,490	125	402	24,700
November	4,400	116	1,170	69,600
December	570	43	99	6,090
The year	4,400	42	283	205,000
1918.				
January	630	45	167	10,300
February	450	43	90.1	5,000
March	89	43	54.3	3,340
April	402	53	152	9,040
May	410	110	227	14,000
June	205	60	144	8,570
July	530	72	140	8,610
August	375	62	234	14,400
September	260	45	81.0	4,820
October	1,770	67	480	29,500
November	1,950	65	357	21,200
December	1,000	53	231	14,200
The year	1,950	43	198	143,000

Monthly discharge of Ketchikan Creek at Ketchikan for 1917–1919—Continued.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1919.				
January	1,000	62	247	15,200
February	230	55	92.1	5,120
March	650	51	98.9	6,080
April	950	89	294	17,500
May	725	80	238	14,600
June	570	125	195	11,600
July	390	95	137	8,420
August	725	67	135	8,300
September	1,650	60	266	15,800
October	410	62	107	6,580
November	1,590	62	400	24,200
December 1-17	700	55	143	4,820
The year				138,000

FISH CREEK NEAR SEALEVEL, REVILLAGIGEDO ISLAND.

LOCATION.—In latitude 55° 24′ W., near outlet of Lower Lake on Fish Creek, 600 feet from tidewater at head of Thorne Arm, 2 miles northwest of mine at Sealevel, and 25 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 19, 1915, to December 31, 1919.

GAGE.—Stevens water-stage recorder on right shore of Lower Lake, 200 feet above outlet.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across creek, 1 mile upstream from gage and 500 feet above head of Lower Lake; at low stages made by wading at cable. Only one small creek enters Lower Lake, at point opposite gage, between the cable site and control.

CHANNEL AND CONTROL.—The lake is about 500 feet wide opposite the gage. Outlet consists of two channels, each about 60 feet wide, separated by an island 40 feet wide. From the lake to tidewater, 200 feet, the creek falls about 20 feet. Bedrock exposed at the outlet of the lake forms a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage during year from water-stage recorder 4.78 feet at 11 p. m., December 18 (discharge computed from an extension of rating curve, 3,810 second-feet); minimum stage, 0.63 foot, March 19 (discharge, 40 second-feet).

1915–1919: Maximum stage recorded, 5.33 feet November 1, 1917 (discharge, 4,600 second-feet); minimum stage, 0.50 foot, February 11, 1916 (discharge, 22 second-feet).

ICE.—Lower Lake freezes over, but as gage is set back in the bank ice does not form in well, and the relatively warm water from the lake and the swift current keep the control open.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined below and extended above 1,500 second-feet. Operation of water-stage recorder satisfactory except for period indicated by break in record shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records good, except for short period of break in record, for which they are fair.

There are three large lakes in the upper drainage basin. Big Lake, 2 miles from beach at an elevation of 275 feet, covers 1,700 acres; Third Lake, 250 acres; and Mirror Lake, at an elevation of 1,000 feet, 800 acres. Two-thirds of the drainage basin is

covered with a thick growth of timber and brush interspersed with occasional patches of beaver swamp and muskeg. Only the tops of the highest mountains are bare. This large area of lake surface and vegetation, notwithstanding the steep slopes and shallow soil, affords a little ground storage and after a heavy precipitation maintains a good run-off. During a dry, hot period in summer, however, after the snow has melted, the flow becomes very low because of lack of ice or glaciers in the drainage basin.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Fish Creek near Sealevel for 1919.

Day.	Jan.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	157	65	1,960	539	351	312	172	116	132	228	139
2	153	62	1,620	421	395	285	168	106	116	238	116
3	188	60	1,100	329	512	280	164	98	119	210	106
4	790	58	806	285	595	351	157	89	202	....	....
5	1,200	56	726	250	512	466	157	84	296	....	....
6	965	56	595	254	428	460	168	84	324	....	....
7	1,690	55	473	285	368	408	168	80	408	....	....
8	1,960	53	378	351	330	356	161	78	546	....	....
9	1,560	55	334	408	345	329	149	73	492	....	....
10	1,060	56	285	402	395	302	142	69	408	104	....
11	790	56	280	378	408	296	132	69	403	104	....
12	560	51	285	368	384	285	123	69	460	94	....
13	492	50	275	362	356	296	116	80	460	123	....
14	368	48	243	378	351	340	132	123	356	307	50
15	296	50	233	492	345	384	285	129	275	525	51
16	249	48	....	610	351	378	539	142	220	766	123
17	197	45	....	595	345	351	492	210	176	1,070	470
18	172	42	....	512	351	324	395	710	149	1,960	3,110
19	161	40	....	595	368	296	368	963	142	1,840	2,940
20	136	45	....	920	492	275	866	938	312	1,460	1,460
21	126	60	....	875	610	254	806	655	460	1,200	806
22	....	94	....	632	560	243	539	648	506	875	553
23	....	126	....	506	567	238	378	595	460	710	595
24	....	123	312	610	610	224	275	447	340	553	625
25	....	111	312	830	539	220	210	351	250	408	....
26	....	104	525	790	440	220	168	307	206	312	....
27	....	91	947	686	434	210	149	250	168	250	....
28	....	157	938	610	395	210	132	210	161	228	1,080
29	....	312	875	506	362	206	116	172	168	197	734
30	....	1,010	670	460	340	202	116	153	176	165	492
31	....	1,620	....	384	....	188	123	....	224	....	346

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, from maximum and minimum stages indicated by recorder and by comparison with hydrographs of other stations: Jan. 22–31, 140 second-feet; Feb. 1–28, 155 second-feet; Apr. 16–23, 320 second-feet; June 8 and 9, as shown in table; Nov. 4–9, 120 second-feet; Dec. 4–13, 70 second-feet; and Dec. 25–27, 1,100 second-feet.

Monthly discharge of Fish Creek near Sealevel for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	1,960	....	473	29,100
February	....	....	155	8,610
March	1,620	40	157	9,650
April	1,960	....	558	33,200
May	920	254	504	31,000
June	610	330	428	25,500
July	466	188	296	18,200
August	866	116	260	16,000
September	963	69	271	16,100
October	546	116	294	18,100
November	1,960	....	489	29,100
December	3,110	....	573	35,200
The year	3,110	40	373	270,000

SWAN LAKE OUTLET AT CARROLL INLET, REVILLAGIGEDO ISLAND.

LOCATION.—Halfway between Swan Lake and tidewater, on east shore of Carroll Inlet 1 mile from its head, 30 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—August 24, 1916, to December 31, 1919.

GAGE.—Stevens water-stage recorder on left bank, half a mile from tidewater; reached by a trail which leaves beach back of old cabin one-fourth mile south of mouth of creek. Gage was washed out by extreme high water in November, 1917. New gage installed 10 feet farther back in bank at old datum, but with a new control, on May 5, 1918.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from a cable across stream 100 feet downstream from gage; at low stages, made by wading.

CHANNEL AND CONTROL.—The gage well is in a deep pool 25 feet upstream from a contracted portion of the channel, where a fall of 1 foot over bedrock forms a permanent control. The effect of the violent fluctuation of the water surface outside of the gage well is decreased in the inner float well, because the intake holes at the bottom are very small. At the cable section the bed is rough, the water shallow, and the current very swift. Point of zero flow is at gage height −1.0 foot.

EXTREMES OF DISCHARGE.—Maximum stage during year, from water-stage recorder, 6.55 feet at 10 a. m., December 18 (discharge, computed from extension of rating curve, 3,700 second-feet); minimum stage, −0.04 foot March 19–20 (discharge, 36 second-feet).

1915–1918: Maximum stage occurred probably on November 1, 1917 (discharge, estimated by comparison with Fish Creek, 5,500 second-feet); minimum discharge, 36 second-feet, March 19–20, 1919.

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve, determined by five discharge measurements and point of zero flow, is fairly well defined below 2,000 second-feet. Water-stage recorder operated satisfactorily except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharges obtained by applying to rating table mean gage heights for regular intervals of day. Results good except for periods of break in record, for which they are fair.

Swan Lake, whose area is about 350 acres, is 1½ miles from tidewater, at an elevation of 225 feet.

Discharge measurements of Swan Lake outlet at Carroll Inlet during 1919.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Mar. 2	0.23	61
Aug. 30	.95	201

Daily discharge, in second-feet, of Swan Lake outlet at Carroll Inlet for 1919.

Day.	Jan.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Nov.	Dec.
1	176	....	2,240	505	390	390	294	181	....	150
2	170	....	1,540	390	477	374	282	156	....	132
3	188	....	1,020	328	684	397	277	139	....	118
4	720	....	770	306	711	621	274	124	....	107
5	875	....	711	309	577	730	274	118	....	98
6	711	....	577	358	473	621	309	120	....	90
7	1,500	....	445	437	437	533	306	118	....	84
8	1,610	55	358	537	441	465	274	112	103	79
9	1,540	53	303	553	321	441	265	107	126	74
10	1,050	54	280	473	577	418	262	111	114	70
11	745	54	277	465	573	418	257	118	103	66
12	517	54	271	465	505	429	229	143	94	63
13	418	52	251	441	461	473	218	254	143	60
14	384	50	235	608	449	545	254	257	248	59
15	343	50	213	930	433	545	384	221	577	78
16	297	47	193	902	433	481	706	193	760	196
17	254	44	203	720	437	445	590	936	1,420	1,410
18	213	44	274	735	449	411	465	1,750	2,640	3,470
19	176	43	414	1,320	565	384	425	1,500	2,000	2,400
20	141	43	425	1,290	848	364	1,110	1,020	1,470	1,260
21	137	92	400	875	848	358	960	735	1,290	745
22	143	107	343	621	745	340	621	795	875	698
23	141	103	343	497	795	321	425	....	630	1,020
24	135	87	374	726	735	321	321	....	497	1,020
25	132	78	433	1,170	594	343	411	....	374	1,230
26	128	72	848	902	537	337	218	....	297	1,320
27	....	68	1,140	693	521	334	193	....	257	1,170
28	....	111	902	608	473	340	181	....	226	1,020
29	....	210	730	509	457	343	174	....	196	698
30	....	1,260	630	437	425	328	193	....	170	....
31	....	1,890	....	397	....	303	198	....	....	....

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, by comparison with records for Fish Creek: Jan. 14–19, as shown in table; Jan. 27–31, 140 second-feet. From maximum and minimum stages indicated by recorder and by comparison with record for other stations as follows: Feb. 1–28, 120 second-feet; Mar. 1–7, 60 second-feet; Sept. 23–30, 350 second-feet; Oct. 1–31, 340 second-feet; Nov. 1–7, 200 second-feet. Discharge, Dec. 30–31, estimated at 400 second-feet by comparison with record for Fish Creek.

Monthly discharge of Swan Lake outlet at Carroll Inlet for 1919.

Month.	Discharge in second-feet.			Run-off (in acre-feet).
	Maximum.	Minimum.	Mean.	
January	1,610	....	437	26,900
February	....	....	120	6,660
March	1,890	43	166	10,200
April	2,240	193	571	34,000
May	1,320	306	629	38,700
June	848	321	546	32,500
July	730	303	424	26,100
August	1,110	174	366	22,500
September	1,750	....	400	23,800
October	....	....	340	20,900
November	2,640	94	534	31,800
December	3,470	59	638	39,200
The year	3,470	43	433	313,000

ORCHARD LAKE OUTLET AT SHRIMP BAY, REVILLAGIGEDO ISLAND.

LOCATION.—In latitude 55° 50′ N., longitude 131° 27′ W., at outlet of Orchard Lake, one-third mile from tidewater at head of Shrimp Bay, an arm of Behm Canal 46 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 28, 1915, to December 31, 1919.

GAGE.—Stevens water-stage recorder on right bank 300 feet below Orchard Lake and 100 feet above site of timber-crib dam, which was built in 1914 for proposed pulp mill and washed out by high water August 10, 1915. Datum of gage lowered 2 feet September 15, 1915. Gage heights May 29 to August 10 referred to first datum; August 11, 1915, to August 17, 1916, to second datum. Datum of gage lowered 1 foot August 17, 1916. Gage heights August 18 to December 31, 1916, referred to this datum. Gage washed out probably during high water on November 1, 1917. New gage installed on April 28, 1918, at old site at the datum of August 17, 1916.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable 5 feet upstream from gage; at low stages by wading one-fourth mile below gage.

CHANNEL AND CONTROL.—From Orchard Lake, at elevation 134 feet above high tide, the stream descends in a series of rapids for 1,000 feet through a narrow gorge, then divides into two channels and enters the bay in two cascades of 100-foot vertical fall. Opposite the gage the water is deep and the current sluggish. At the site of the old dam bedrock is exposed, but for 30 feet upstream the channel is filled in with loose rock and brush placed during construction of dam. This material forms a riffle which acts as a control for water surface at gage at low and medium stages and is scoured down when ice goes out of lake; the rock outcrop at site of old dam acts as a control at high stages and is permanent.

EXTREMES OF DISCHARGE.—Maximum stage during year from water-stage recorder, 9.65 feet at 12 p. m. December 18 (discharge, 6,660 second-feet); minimum stage recorded, —0.02 foot March 19 (discharge, 35 second-feet).

1915–1919: Maximum stage occurred, probably, on November 1, 1917 (discharge estimated by multiplying maximum discharge at Fish Creek on that date by 1.55, which is the ratio between the maximum discharges of Orchard Lake outlet and Fish Creek on October 16 and 15, 1915, 7,100 second-feet); minimum discharge, estimated, 20 second-feet February 11, 1916.

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation changes occasionally during high water. Rating curve, determined by five discharge measurements made since new gage was installed, point of zero flow, and form of upper portion of old rating curve, is well defined below 4,000 second-feet. Water-stage recorder operating satisfactory except for periods indicated in footnote to daily-discharge table Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records good, except for period of break in record, for which they are fair.

The highest mountains on this drainage basin are only 3,500 feet above sea level and are covered to an elevation of 2,500 feet by a heavy stand of timber and a thick undergrowth of brush, ferns, alders, and devil's club. The topography is not so rugged as that of the area surrounding Shelockum Lake, and the proportion of vegetation, soil cover, and lake area is greater, so that more water is stored and the flow in the Orchard Lake drainage is better sustained.

Discharge measurements of Orchard Lake outlet at Shrimp Bay during 1919.

[Made by G. H. Canfield.]

Date.		Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Mar. 4		0.21	59
Sept. 3		1.17	193

Daily discharge, in second-feet, of Orchard Lake outlet at Shrimp Bay for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Dec.
1	172	99	77	2,530	660	620	600	374	323	....
2	166	92	72	1,550	522	720	560	368	212	....
3	232	85	63	1,080	433	1,000	580	353	203	....
4	1,070	84	57	880	407	1,060	762	347	166	....
5	1,310	81	55	762	426	880	980	359	148	....
6	955	75	54	660	573	762	830	362	145	....
7	2 090	75	53	514	720	720	740	338	140	....
8	2,000	75	51	400	905	720	640	306	131	66
9	1,980	94	51	338	855	785	596	323	125	64
10	1,310	148	52	326	700	855	572	320	122	64
11	980	203	51	338	660	830	580	291	130	64
12	660	203	48	329	660	785	588	272	145	65
13	522	176	46	308	616	740	628	254	214	65
14	440	150	44	296	855	700	628	257	225	66
15	353	140	42	254	1,280	700	628	317	201	66
16	272	148	41	235	1,130	700	604	572	174	90
17	216	208	40	280	930	700	600	529	951	1,140
18	188	230	37	485	1,030	720	568	474	1,860	5,790
19	164	244	35	660	1,890	830	532	492	1,820	3,040
20	138	240	37	612	1,680	1,060	514	1,250	1,160	1,450
21	125	207	44	522	1,080	1,030	511	1,110	880	680
22	125	162	61	426	762	905	474	710	980	740
23	128	140	83	467	680	980	447	503	680	1,310
24	121	124	97	580	1,430	880	443	308	....	1,490
25	119	113	97	700	1,430	700	471	286	....	1,680
26	115	105	94	1,030	1,030	640	453	235	....	1,960
27	108	96	87	1,490	880	640	450	207	....	1,160
28	106	84	110	1,160	785	640	467	194	....	1,080
29	106	....	398	930	700	680	460	212	....	660
30	110	....	1,910	762	660	660	420	344	....	433
31	105	....	2,410	....	620	....	384	400	....	305

NOTE.—Daily discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder: Feb. 22 to Mar. 3, by comparison with hydrographs for other stations: Apr. 8 and 9, by interpolation: May 27 to June 16, from gage-height graph drawn through maximum and minimum stages shown by recorder and by comparison with record for Swann Lake outlet. Discharge for following periods estimated from maximum and minimum stages indicated by recorder and by comparison with records for other stations: Sept. 24–30, 320 second-feet; Oct. 1–31, 500 second-feet; Nov. 1–12, 200 second-feet; Nov. 13–30, 850 second-feet; and Dec. 1–7, 100 second-feet.

Monthly discharge of Orchard Lake outlet at Shrimp Bay for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	2,090	105	532	32,700
February	244	75	139	7,720
March	2,410	35	206	12,700
April	2,530	235	696	41,400
May	1 890	407	869	53,400
June	1,060	620	788	46,900
July	980	384	571	35,100
August	1,250	194	411	25,300
September	1,860	122	447	26,600
October	....	....	500	30,700
November	....	....	590	35,100
December	5,790	....	791	48,600
The year	5,790	35	548	396,000

SHELOCKUM LAKE OUTLET AT BAILEY BAY.

LOCATION.—In latitude 56° 00′ N., longitude 131° 36′ W., on mainland near outlet of Shelockum Lake, three-fourths mile by Forest Service trail from tidewater at north end of Bailey Bay and 52 miles by water north of Ketchikan.

DRAINAGE AREA.—18 square miles (measured on sheets Nos. 5 and 8 of the Alaska Boundary Tribunal, edition of 1895).

RECORDS AVAILABLE.—June 1, 1915, to October 31, 1919. (Gage-height graph, December 8–31, 1919, could not be removed from recorder, because of ice in bay, in time for inclusion in this bulletin.)

GAGE.—Stevens continuous water-stage recorder on right shore of lake, 250 feet above outlet. Gage house was pushed off the well by a snowslide January 4, 1917. Gage not put into operation again until May 23, 1917.

DISCHARGE MEASUREMENTS.—Made from cable across outlet of lake, 200 feet below gage and 50 feet upstream from crest of falls.

CHANNEL AND CONTROL.—Opposite the gage the lake is 600 feet wide; at the outlet bedrock is exposed and the water makes a nearly perpendicular fall of 150 feet. This fall forms an excellent and permanent control for the gage. At extremely high stages the lake has another outlet about 200 feet to left of main outlet. Point of zero flow is at gage height 0.6 foot.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year occurred, probably, on December 13; minimum discharge (estimated from hydrograph for Fish Creek to have occurred March 21), 8 second-feet.

1915–1919: Maximum stage, 6.84 feet at 8 a. m. November 1, 1917 (discharge, 2,780 second-feet); minimum discharge, estimated from climatic records, 2.5 second-feet, January 31, 1917.

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined. Operation of water-stage recorder satisfactory except for periods of break in record shown in the footnote to daily-discharge table. Daily discharge ascertained by applying to the rating table mean daily gage height determined by inspection of gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records excellent, except for periods of break in record, for which they are fair.

Shelockum Lake, at an elevation of 344 feet, covers only 350 acres. The drainage basin above the lake is rough, precipitous, and covered with little soil or vegetation. There are no glaciers or ice fields at the source of the tributary streams. Therefore, because of little natural storage, the run-off after a heavy rainfall is rapid and not well sustained, and during a dry summer or winter the flow becomes very low. The large amount of snow that accumulates on the drainage basin during the winter maintains a good flow in May and June.

The following discharge measurement was made by G. H. Canfield:

March 4, 1919: Gage height, 1.14 feet; discharge, 15 second-feet.

Daily discharge, in second-feet, of Shelockum Lake outlet at Bailey Bay for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept
1	51				220	220	250	172	96
2	73				190	252	241	168	71
3	115				164	350	245	162	64
4	350		18		150	392	363	160	55
5	299		17		160	336	490	164	50
6	620		18		210	311	407	164	48
7	730		19		287	292	336	156	45
8	438		19		363	292	292	145	42
9			20		350	306	277	137	39
10			21		275	304	275	132	40
11			20		241	301	270	119	48
12			19		263	299	287	110	65
13			17		252	294	363	100	156
14			17		311	292	392	123	176
15			16		490	287	363	184	141
16					392	282	311	392	110
17					311	280	287	455	453
18					299	287	275	316	1,180
19					422	336	252	287	860
20	45				378	508	287	660	472
21	43				311	508	226	455	407
22	45				287	407	216	275	525
23	45				263	407	204	180	311
24	45				378	369	206	132	220
25	43				363	306	216	102	
26	41			542	311	275	210	84	
27	41			640	287	277	210	73	
28	41			472	263	275	210	68	
29	48			336	252	273	208	75	
30	57			263	241	259	196	100	
31	48				230		180	140	

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, from maximum and minimum stages indicated by recorder and by comparison with hydrographs for other stations: Jan. 9-19, 115 second-feet; Feb 1-28, 45 second-feet; Mar. 1-3, 20 second-feet; Mar. 16-31, 75 second-feet; Apr. 1-25, 220 second-feet; Aug. 28 to Sept. 1, daily discharge as shown in table; Sept. 25-30, 110 second-feet; and Oct. 1-31, 200 second-feet.

Monthly discharge of Shelockum Lake outlet at Bailey Bay for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	730	41	145	8,920
February			45	2,500
March			47.8	2,940
April			258	15,400
May	490	150	288	17,700
June	508	220	319	19,000
July	490	180	274	16,800
August	660	68	193	11,900
September	1,180	39	211	12,600
October			200	12,300
The period				120,000

KARTA RIVER AT KARTA BAY, PRINCE OF WALES ISLAND.

LOCATION.—In latitude 55° 34′ N., longitude 132° 37′ W., at head of Karta Bay, an arm of Kasaan Bay, on east coast of Prince of Wales Island, 42 miles by water across Clarence Strait from Ketchikan.

DRAINAGE AREA.—49.5 square miles (U. S. Forest Service reconnaissance map of Prince of Wales Island, 1914).

RECORDS AVAILABLE.—July 1, 1915, to December 31, 1919.

GAGE.—Stevens continuous water-stage recorder on left bank, half a mile above tidewater, at head of Karta Bay and 1¼ miles below outlet of Little Salmon Lake. Two per cent of total drainage of Karta River enters between outlet of lake and gage.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across river 50 feet upstream from gage; at low stages by wading at cable section.

CHANNEL AND CONTROL.—From Little Salmon Lake, 1½ miles from tidewater, the river descends 105 feet in a series of rapids in a wide, shallow channel, the banks of which are low but do not overflow. The bed is of coarse gravel and boulders; rock crops out only at outlet of lake. Gage and cable are at a pool of still water formed by a riffle of coarse gravel that makes a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage during the year from water-stage recorder, 4.75 feet estimated to have occurred December 18 (discharge, from extension of rating curve, 3,900 second-feet); minimum stage, 0.85 foot, March 19 (discharge, 54 second-feet).

1915–1919: Maximum stage, 5.5 feet November 1, 1917 (discharge, 5,070 second-feet); minimum flow, 21 second-feet, February 11, 1916.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 80 and 1,500 second-feet; extended below 80 second-feet to the point of zero flow and above 1,500 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying gage heights for regular intervals to rating table. Records excellent except for periods of breaks in record, for period affected by ice, and for discharge above 1,500 second-feet, for which they are fair.

The combined area of Little Salmon Lake at elevation 105 feet and Salmon Lake at elevation 110 feet is 1,600 acres. The slopes along the right shore of lakes and at head of Salmon Lake are gentle, and the area included by the 250-foot contour above lake outlet is 5,500 acres. The drainage area to elevation 2,000 feet is heavily covered with timber and dense undergrowth of ferns, brush, and alders. The upper parts of the mountains are covered with thin soil and brush. Only a few peaks at an elevation of 3,500 feet are bare. This large lake and flat area and thick vegetal cover afford considerable natural storage, which, after heavy precipitation, maintains a good run-off. The snow usually melts by the end of June, and the run-off becomes very low during a dry, hot summer.

The Forest Service in the summer of 1916 constructed a pack trail from tidewater to outlet of Little Salmon Lake.

The following discharge measurement was made by G. H. Canfield:

March 6, 1919: Gage height, 0.98 foot; discharge, 85 second-feet.

Daily discharge, in second-feet, of Karta River at Karta Bay for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	176	......	1,700	565	402	238	115	88	160	302	......
2	......	156	......	1,410	474	428	229	109	88	142	290	......
3	......	145	......	1,090	402	441	233	108	83	152	238	......
4	......	142	......	907	356	448	320	97	76	197	215	......
5	......	135	......	880	356	448	350	94	71	220	172	......
6	......	128	83	756	402	422	338	91	69	248	152	......
7	......	121	83	610	480	389	308	88	64	448	128	......
8	......	156	83	522	572	338	314	88	58	515	125	......
9	......	206	83	480	565	344	314	88	58	448	145	......
10	......	248	86	448	558	395	308	86	56	550	152	......
11	......	259	83	434	773	376	296	83	56	572	145	......
12	......	233	81	454	714	350	308	78	56	529	135	......
13	......	233	78	434	633	338	314	78	60	448	......	......
14	633	233	74	415	799	332	338	76	69	363	......	......
15	501	215	71	382	925	332	338	78	69	290	......	......
16	395	269	66	344	943	320	314	145	71	248	......	......
17	308	460	60	344	826	302	285	164	164	215	......	......
18	264	508	58	422	782	296	269	176	1,050	210	......	......
19	228	522	54	683	1,170	338	243	238	1,420	382	......	......
20	196	460	56	714	1,330	382	233	415	1,070	515	......	1,270
21	180	396	91	673	1,080	389	215	320	808	529	......	790
22	192	308	138	580	782	396	206	308	853	515	......	756
23	206	264	168	529	633	382	197	238	681	434	......	1,100
24	197	215	168	558	826	363	180	192	515	350	......	1,060
25	188	192	160	602	1,000	338	172	156	428	290	......	1,470
26	176	164	145	898	826	344	160	132	350	238	......	2,240
27	184	......	152	1,040	665	326	149	112	290	215	......	1,760
28	197	......	184	925	550	302	142	100	238	238	......	1,230
29	196	......	338	835	494	280	135	94	206	215	......	808
30	220	......	961	697	467	254	128	91	180	215	......	580
31	197	......	1,230	......	428	......	121	97	......	302	......	454

NOTE.—Discharge estimated for following periods, because of unsatisfactory operation of water-stage recorder, from maximum and minimum stages indicated by recorder and by comparison with hydrographs for other stations: Jan. 1-13, 1,300 second-feet; Feb. 27-28, 135 second-feet; Mar. 1-5, 100 second-feet; Nov. 13-30, 800 second-feet; Dec. 1-14, 90 second-feet; and Dec. 15-19, 1,500 second-feet.

Monthly discharge of Karta River at Karta Bay for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	....	176	695	42,700
February	522	121	243	13,500
March	1,230	54	172	10,600
April	1,700	344	691	41,100
May	1,330	356	690	42,400
June	448	254	360	21,400
July	350	121	248	15,200
August	415	76	140	8,610
September	1,420	56	312	18,600
October	572	142	335	20,600
November	....	....	553	32,900
December	....	....	719	44,200
The year	....	54	431	312,000

CASCADE CREEK AT THOMAS BAY, NEAR PETERSBURG.

LOCATION.—One-fourth mile above tidewater on each shore of south arm of Thomas Bay; 22 miles by water from Petersburg. One small tributary enters the river from the left half a mile above gage and 2 miles below lake outlet.

DRAINAGE AREA.—21.4 square miles (measured on the United States Geological Survey geologic reconnaissance map of the Wrangell mining district, edition of 1907).

RECORDS AVAILABLE.—October 27, 1917, to December 31, 1919.

GAGE.—Stevens water-stage recorder on left bank, one-fourth mile from tidewater; reached by trail which leaves beach back of old cabin at mouth of creek.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from log footbridge across stream one-fourth mile upstream from gage; at low stages, made by wading.

CHANNEL AND CONTROL.—From the outlet of a lake at an elevation of 1,200 feet above sea level and 3 miles from tidewater the river descends in a continuous series of rapids and falls through a narrow, deep canyon. Gage is in a protected eddy above a natural rock weir, which forms a well-defined and permanent control. The bed of river under the footbridge is rough and the current swift and irregular, but this section is the only place on the whole river where even at low and medium stages there are no boils and eddies.

EXTREMES OF DISCHARGE.—Maximum stage during year from water-stage recorder, 7.0 feet at 10 p. m. September 21 (discharge, from extension of rating curve, 1,570 second-feet); minimum discharge, 20 second-feet, estimated from climatic data and record of flow of Sweetheart Falls Creek.

1917–1919: Maximum stage, 7.65 feet at 11 p. m. November 18, 1917 (discharge computed from extension of rating curve, 1,980 second-feet); minimum stage 0.80 foot about April 6, 1918 (discharge, 17 second-feet).

ICE.—Stage-discharge relation affected by ice for short periods.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined below 1,200 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharge for equal intervals of day. Records good except for periods when recorder did not operate satisfactorily, for which they are fair.

The first site on this stream for a storage reservior is at a small lake 3 miles from tidewater, at an elevation of 1,200 feet above sea level. The drainage area above the gaging station is 21 square miles and above the lake outlet 17 square miles. Flow during summer is augmented by melting ice from glaciers on upper portion of drainage area.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Cascade Creek at Thomas Bay for 1919.

Day.	Feb.	Mar.	Apr.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	....	75	145	380	518	250	146	86	57
2	....	....	60	180	380	485	200	150	76	54
3	....	....	55	192	395	470	167	532	68	51
4	....	....	48	183	485	470	153	890	63	49
5	....	....	47	175	518	518	153	890	57	46
6	....	....	44	167	535	500	150	1,110	54	44
7	....	....	40	183	518	440	160	1,040	50	42
8	....	....	38	200	470	485	183	658	48	40
9	....	....	40	210	470	570	200	410	48	....
10	....	....	39	280	518	518	410	342	46	....
11	....	....	42	280	485	470	605	330	44	....
12	....	....	....	2[illegible]2	500	455	518	270	42	....
13	....	....	....	2[illegible]2	535	455	570	200	54	....
14	25	....	....	270	570	710	588	160	59	....
15	25	....	....	260	622	850	485	134	88	....
16	25	....	....	280	535	978	440	119	87	....
17	26	....	....	318	455	790	672	111	122	....
18	26	....	....	318	380	810	850	109	342	....
19	26	....	....	380	355	910	692	146	280	....
20	26	....	....	605	380	1,320	552	302	270	....
21	24	....	....	570	395	890	976	640	220	....
22	25	....	....	500	395	640	1,140	425	153	....
23	24	....	....	455	395	455	830	260	131	....
24	24	....	....	440	395	368	850	183	112	....
25	23	....	....	410	425	342	1,020	146	96	....
26	23	....	....	440	425	330	675	126	83	....
27	23	....	....	425	470	342	440	121	74	....
28	22	....	....	395	552	395	292	124	69	....
29	....	27	....	395	622	440	220	107	65	....
30	....	70	....	380	640	440	175	94	61	....
31	....	82	....	....	570	342	....	92	....	....

NOTE.—Discharge for following periods estimated, because of ice effect or unsatisfactory operation of water-stage recorder, from hydrograph drawn by comparison with that for Sweetheart Falls Creek through maximum and minimum stages indicated by recorder: Jan. 1–13, 161 second-feet; Feb. 1–13, 30 second-feet; Feb. 26–28, daily discharge; Mar. 1–28, 24 second-feet; Apr. 12–30, 90 second-feet; May 1–31, 155 second-feet, June 1–2, daily discharge; Dec. 9–15, 38 second-feet; and Dec. 16–31, 100 second-feet.

Monthly discharge of Cascade Creek at Thomas Bay for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	....	....	161	9,900
February	....	22	27.0	1,500
March	82	....	27.4	1,680
April	....	38	74.6	4,440
May	....	....	155	9,530
June	605	145	322	19,200
July	640	355	476	29,300
August	1,320	330	571	35,100
September	1,140	150	487	29,000
October	1,110	92	334	20,500
November	342	42	102	6,070
December	....	....	72.5	4,460
The year	1,320	22	236	171,000

GREEN LAKE OUTLET AT SILVER BAY, NEAR SITKA.

LOCATION.—In latitude 56° 59′ N., longitude 135° 5′ W., at outlet of Green Lake, head of Silver Bay, 10½ miles by water south of Sitka.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—August 22, 1915, to December 31, 1919.

GAGE.—Stevens water-stage recorder on right bank, at outlet of lake, reached by trail which leaves the beach one-fourth mile north of mouth of stream, ascends a 600-foot ridge, and then drops down to the outlet of the lake. Gage datum lowered 1 foot December 27, 1916.

DISCHARGE MEASUREMENTS.—Made from cable across outlet 30 feet below gage.

CHANNEL AND CONTROL.—From Green Lake, 240 feet above sea level and 1,800 feet from tidewater, the stream descends in a series of falls and rapids through a narrow canyon whose exposed rock walls rise vertically more than 100 feet.

EXTREMES OF DISCHARGE.—Maximum stage during year, 12.4 feet, probably on October 6, estimated from vertical line traced by recording pencil while clock of recorder did not run (discharge, estimated from extension of rating curve, 3,000 second-feet); minimum stage recorded, −0.05 foot March 27–29 (discharge, 10 second-feet).

1915–1919: Maximum stage recorded, 13.0 feet, September 26, 1918 (discharge, estimated from extension of rating curve, 3,300 second-feet); minimum stage recorded, −0.05 foot March 27–29, 1919 (discharge, 10 second-feet).

ICE.—Ice forms on lake and at gage, but because of current and flow of relatively warm weather from the lake the control remains open.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 10 and 1,300 second-feet. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record, as shown in the footnote to the daily-discharge table. Daily discharge ascertained by applying to the rating table mean daily gage height, determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Records good, except those for periods when gage was not operating satisfactorily, which are fair.

In the fall and winter the flow is low because there is little ground storage, and on most of the drainage area the precipitation is in the form of snow. This accumulated snow produces a large run-off during the spring, and the melting ice from the glacier and the ice-capped mountains augments the run-off from precipitation during the summer. The area of Green Lake is estimated to be about 175 acres. [a]

The discharge measurements were made at the station during the year.

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[a] Supersedes figure published in U. S. Geol. Survey Bulls. 662, 692, and 712.

Daily discharge, in second-feet, of Green Lake outlet at Silver Bay for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Oct.	Nov.	Dec.
1	70	44	16	147	138	172	303	....	....	....	66
2	142	43	16	164	114	212	354	....	....	....	60
3	188	40	15	140	100	233	461	....	....	....	60
4	144	40	....	132	97	233	620	....	....	....	60
5	173	38	....	130	102	212	673	....	....	....	57
6	713	38	....	126	124	206	557	....	....	....	62
7	1,580	38	....	100	206	200	547	....	....	....	69
8	820	34	....	85	286	194	547	....	....	....	59
9	568	36	....	79	294	240	547	....	....	....	46
10	557	42	....	76	226	286	547	....	....	....	38
11	480	48	....	73	337	380	557	....	....	....	37
12	226	43	....	73	182	328	599	....	....	....	38
13	177	38	....	76	247	354	588	....	....	....	40
14	138	38	....	76	312	312	630	....	....	....	43
15	122	33	....	70	470	286	518	461	....	....	44
16	107	32	....	67	442	312	397	433	....	....	....
17	92	37	....	66	490	362	346	415	....	....	....
18	80	42	....	85	303	371	337	371	....	....	....
19	73	58	....	134	397	490	362	433	182	....	....
20	67	59	12	156	528	652	388	641	338	....	....
21	66	48	18	142	406	547	406	489	820	....	....
22	67	40	18	116	262	588	288	371	397	....	....
23	67	36	16	107	212	620	388	303	219	....	....
24	61	30	14	126	226	508	380	....	172	....	....
25	59	27	12	154	303	499	354	....	142	....	....
26	55	24	11	240	240	452	362	....	126	....	....
27	55	18	10	294	194	415	452	....	134	....	....
28	53	18	10	219	168	415	652	....	....	....	....
29	60	....	10	168	162	388	706	....	....	....	....
30	57	....	12	155	164	346	652	....	....	79	....
31	51	....	30	....	166	....	518	....	....	....	....

NOTE.—Discharge for following periods extimated, because of unsatisfactory operation of water-stage recorder, by comparison with hydrographs for other stations: Mar. 3, 15 second-feet and Mar. 4-19, 15 second-feet; from maximum and minimum stages indicated by recorder and by comparison with record of flow for Sweetheart Falls Creek: Aug. 1-14, 500 second-feet; Aug. 24-31, 385 second-feet; Sept. 1-30, 500 second-feet; and Oct. 1-18, 500 second-feet; from maximum and minimum stages indicated by recorder and by comparison with climatic data for Juneau and hydrographs of other stations: Oct. 28-31, 155 second-feet; Nov. 1-29, 185 second-feet; and Dec. 16-31, 200 second-feet.

Monthly discharge of Green Lake outlet at Silver Bay for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	1,580	51	231	14,200
February	59	18	37.9	2,100
March	30	10	14.8	910
April	294	66	126	7,500
May	528	97	255	15,700
June	652	172	358	21,300
July	706	303	488	30,000
August	....	....	452	27,800
September	....	....	500	29,800
October	....	....	392	24,100
November	....	....	181	10,800
December	....	37	128	7,870
The year	1,580	10	265	192,000

BARANOF LAKE OUTLET AT BARANOF, BARANOF ISLAND.

LOCATION.—In latitude 57° 5′ N., longitude 134° 54′ W., at townsite of Baranof, at head of Warm Spring Bay, east coast of Baranof Island, 18 miles east of Sitka across island but 96 miles from Sitka by water through Peril Strait.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—June 28, 1915, to December 31, 1919.

GAGE.—Stevens water-stage recorder on right bank 700 feet below Baranof Lake and 800 feet above tidewater at head of Warm Spring Bay.

DISCHARGE MEASUREMENTS.—At medium and high stages, from cable across stream 100 feet below lake and 600 feet above gage; at low stages, by wading 100 feet below cable.

CHANNEL AND CONTROL.—From Baranof Lake, at elevation 130 feet above sea level and 1,500 feet from tidewater, the stream descends in a series of rapids and small falls and enters the bay in a cascade of about 100 feet concentrated fall. The bed is of glacial drift, boulders, and rock outcrop. The gage is in an eddy 50 feet downstream from the foot of a small fall and 100 feet upstream from a riffle which forms a well-defined control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 4.78 feet at 3 p. m., October 6 (discharge, computed from an extension of rating curve, 2,610 second-feet); minimum flow, estimated by comparison with record of flow for Green Lake outlet, 20 second-feet, March 27–29.

1915–1919: Maximum stage recorded during period, 5.3 feet August 10, 1915 (discharge, computed from extension of rating curve, 3,350 second-feet); minimum flow, estimated, 20 second-feet, March 27–29, 1919.

ICE.—Because of the swift current and flow of relatively warm water from the lake the stream remains open.

DIVERSIONS.—The flume to Olsen's sawmill diverts from the stream 200 feet below gage only sufficient water to operate a 25-horsepower Pelton water wheel.

ACCURACY.—Stage-discharge relation permanent, not affected by ice. Rating curve well defined below 2,000 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharge for equal intervals of day. Records good except for periods when recorder did not operate satisfactorily and for periods when water was frozen in well, for which they are roughly approximate.

The drainage area is rough and precipitous, and the vegetable and soil cover is thin, even on the foothills of the mountains. The run-off is rapid, and the ground storage is small. During a hot, dry period, however, the flow is greatly augmented by melting ice from several small glaciers and ice-capped mountains.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Baranof Lake outlet at Baranof for 1919.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	....	255	396	640	....	392	279	171
2	....	222	436	640	....	221	435	141
3	....	197	450	668	....	285	1,540	124
4	....	187	450	890	....	261	2,000	110
5	....	191	436	1,100	....	252	1,940	94
6	....	225	456	1,010	....	252	2,320	83
7	....	297	468	930	....	264	1,540	84
8	....	380	456	820	....	300	855	80
9	....	420	500	788	....	424	545	....
10	....	460	615	820	....	615	476	....
11	....	788	640	890	....	590	392	....
12	....	695	640	1,060	....	640	345	....
13	....	545	668	1,100	....	1,940	285	....
14	....	725	668	1,140	....	1,650	255	....
15	....	970	615	930	....	1,010	230	....
16	....	820	590	725	....	755	230	....
17	119	615	615	640	....	890	230	....
18	129	590	615	590	....	1,330	270	....
19	173	695	725	615	....	1,060	291	....
20	235	788	930	668	....	788	500	....
21	252	640	855	725	....	1,540	545	....
22	285	522	855	....	....	1,430	396	....
23	242	464	890	....	....	855	306	....
24	261	590	855	....	....	1,010	255	....
25	282	615	820	....	....	1,380	218	....
26	321	484	820	....	....	820	193	....
27	366	404	788	....	....	545	191	....
28	348	356	788	....	....	420	189	....
29	312	342	755	....	590	352	183	....
30	291	348	668	....	590	321	203	....
31	....	366	....	....	500	....	193	....

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of gage, by comparison with record for Green Lake outlet: Jan. 1–31, 280 second-feet; Feb. 1–28, 60 second-feet; Mar. 1–31, 30 second-feet; Apr. 1–16, 170 second-feet. Discharge for following periods estimated by comparison with record for Sweetheart Falls Creek: June 3–4, 450 second-feet; July 22–31, 825 second-feet; Aug. 1–28, 770 second-feet. Following periods estimated from maximum and minimum stages shown by gage and by comparison with records for other stations: Nov. 9–30, 210 second-feet; Dec. 1–15, 55 second-feet; Dec. 16–31, 215 second-feet.

Monthly discharge of Baranof Lake outlet at Baranof for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	....	....	280	17,200
February	....	....	60	3,330
March	....	....	30	1,840
April	....	....	210	12,500
May	970	187	490	30,100
June	930	396	649	38,600
July	....	....	827	50,800
August	....	....	750	46,100
September	1,940	252	756	45,000
October	2,320	183	575	35,400
November	....	....	184	10,900
December	....	....	138	8,480
The year	....	....	415	300,000

SWEETHEART FALLS CREEK NEAR SNETTISHAM.

LOCATION.—In latitude 57° 56½′ N., longitude 133° 41′ W., on east shore 1 mile from head of south arm of Port Snettisham, 3 miles south of mouth of Whiting River, 7 miles by water from Snettisham, and 42 miles by water from Juneau. No large tributaries enter river between gaging station and outlet of large lake, 2½ miles upstream.

DRAINAGE AREA.—27 square miles (measured on United States Geological Survey topographic map of the Juneau gold belt, edition of 1905).

RECORDS AVAILABLE.—July 31, 1915, to March 31, 1917; May 21, 1918, to December 31, 1919.

GAGE.—Stevens water-stage recorder on right bank, 300 feet upstream from tidewater on east shore of Port Snettisham. Gage washed out in November, 1917, and record from April 20, 1917, lost with gage. New Stevens water-stage recorder installed May 21, 1918, at same datum and at approximate location of old gage.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from cable across river one-fourth mile upstream from gage; at low stages, made by wading in channel at mouth of creek exposed at low tide.

CHANNEL AND CONTROL.—From the outlet of the lake at an elevation of 520 feet above sea level and 2½ miles from tidewater the water descends in a series of rapids and falls through a narrow, deep canyon. Gage is in a pool at foot of two falls, each 25 feet high, which are known as Sweetheart Falls; outlet of pool is a natural rock weir, which forms a well-defined and permanent control for gage.

EXTREMES OF DISCHARGE.—Maximum stage during year from water-stage recorder, 6.0 feet at 10 p. m. October 6 (discharge computed from extension of rating curve, 2,260 second-feet); minimum stage, 0.15 foot 12 a. m. March 29 (discharge, 28 second-feet).

1915–1919 (except for period of no record): Maximum stage recorded, 7.15 feet at midnight, September 26, 1918 (discharge, computed from an extension of the rating curve, 2,880 second-feet); minimum flow, estimated from discharge measurement and climatic data, 15 second-feet February 11, 1916.

ICE.—Stage-discharge relation affected by ice only for short periods during extremely cold weather.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 40 and 1,300 second-feet; extended beyond these limits by estimation. Operation of water-stage recorder satisfactory except for periods shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Records excellent except for periods of ice effect or break in record and for discharge above 1,300 second-feet, for which they are fair.

In the fall and winter the run-off is small because the precipitation is in the form of snow, and because of the small amount of ground storage; during a hot, dry period the low run-off from the ground and lake stage is augmented by melting ice from one glacier.

The following discharge measurement was made by G. H. Canfield:

February 16, 1919: Gage height, 0.35 foot; discharge, 48 second-feet.

Daily discharge, in second-feet, of Sweetheart Falls Creek near Snettisham for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	102	73	42	82	240	324	565	645	545	264	121	76
2	141	67	41	98	199	351	545	565	435	216	113	70
3	176	62	41	90	176	428	505	525	348	418	102	66
4	169	58	42	90	164	449	525	470	285	1,120	90	62
5	300	55	50	141	159	424	585	526	240	1,280	84	58
6	745	58	60	141	164	382	705	605	216	2,010	79	57
7	845	50	60	119	183	365	865	565	202	2,010	74	54
8	945	49	57	109	240	365	805	565	199	1,350	70	50
9	805	48	47	108	285	393	705	645	196	885	70	44
10	585	48	42	102	294	470	705	665	255	545	67	42
11	505	49	37	96	294	525	645	585	452	386	64	41
12	365	49	34	95	294	585	585	525	488	315	62	40
13	285	47	37	92	300	585	565	488	545	258	60	39
14	225	60	44	92	306	525	645	526	925	210	64	41
15	178	52	39	90	372	488	685	705	905	176	72	52
16	152	48	33	87	463	470	625	705	705	152	85	59
17	131	47	37	85	460	525	545	665	565	146	113	113
18	113	82	38	90	442	545	525	605	685	144	270	435
19	102	64	38	117	488	545	488	665	845	164	488	382
20	93	64	48	125	645	625	505	968	725	231	442	276
21	85	58	60	129	605	725	545	968	705	585	460	196
22	87	53	58	127	488	685	565	745	1,010	565	390	159
23	90	47	48	125	410	645	565	545	1,060	390	285	144
24	90	46	39	131	382	625	545	435	990	285	210	148
25	87	44	34	183	410	605	525	382	1,170	213	150	171
26	74	44	32	300	428	705	505	348	1,170	174	127	300
27	104	44	30	400	393	785	525	324	905	148	113	330
28	88	43	30	365	354	685	605	330	605	141	104	249
29	90	....	29	315	327	625	745	393	428	137	93	188
30	87	....	38	285	315	585	825	585	330	129	84	149
31	79	....	42	....	309	....	745	625	....	125	....	133

NOTE.—Daily discharge for following periods estimated by comparison with hydrograph for Cascade Creek, because stage-discharge relation was affected by ice or because of unsatisfactory operation of water-stage recorder: Jan. 5–8, Feb. 27 to Mar. 5, Apr. 1–7, and Dec. 10–12.

Monthly discharge of Sweetheart Falls Creek near Snettisham for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	945	74	256	15,700
February	82	43	53.9	2,990
March	60	29	42.2	2,590
April	400	82	147	8,750
May	645	159	342	21,000
June	785	324	535	31,800
July	865	488	613	37,700
August	968	324	577	35,500
September	1,170	196	604	35,900
October	2,010	125	489	30,100
November	488	60	154	9,160
December	435	39	136	8,360
The year	2,010	29	331	240,000

CRATER LAKE OUTLET AT SPEEL RIVER, PORT SNETTISHAM.

LOCATION.—At outlet of Crater Lake, 1 mile upstream from edge of tide flats at head of north arm of Port Snettisham, 2 miles by trail from cabins of Speel River project, which are 42 miles by water from Juneau.

DRAINAGE AREA.—11.9 square miles above water-stage recorder at lake outlet, and 13 square miles above staff gage at beach (measured on topographic maps of the Alaska Boundary Tribunal, edition of 1895).

RECORDS AVAILABLE.—January 23, 1913, to December 31, 1919.

GAGE.—Stevens water-stage recorder on left shore of lake 100 feet upstream from outlet. A locally made water-stage recorder having a natural vertical scale and a time scale of 7 inches to 24 hours was used until replaced by Stevens gage June 29, 1916. The gage datum remained the same during the period. During the winter, because of inaccessible location and deep snow, the operation of the gage at the lake was discontinued, and the stage read at staff gage in channel exposed at low tide at beach. The first gage at beach was set at an unknown datum and washed out in winter of 1915–16. Another staff gage was set at about the same location November 24, 1916. Other staff gages were set at about the same location January 11 and November 13, 1918.

DISCHARGE MEASUREMENTS.—Made from cable across outlet of lake, 100 feet downstream from gage and 10 feet upstream from crest of first falls. The rope sling from which discharge measurements were first made was replaced in fall of 1915 by a standard U. S. Geological Survey gaging car, making more reliable measurements possible.

CHANNEL AND CONTROL.—The gage is on left shore of lake, 100 feet upstream from outlet, where the stream becomes constricted into a narrow channel, the bed of which is composed of large boulders and rock outcrops that form a well-defined and permanent control.

EXTREMES OF DISCHARGE.—1913–1919: Maximum stage occurred, probably, on September 26, 1918 (discharge, 2,300 second-feet, estimated by multiplying maximum discharge at Long River on September 27, 1918, by 0.44, which is the ratio between the maximum discharges of Crater Lake outlet and Long River on August 19 and 20, 1917; minimum discharge, 5 second-feet, February 1–13, 1916, estimated from one discharge measurement and by comparison with climatic data, and February 13, 1919.

ACCURACY.—Stage-discharge relation permanent. Rating curve defined by 19 discharge measurements, 13 of which were made by employees of the Speel River Project (Inc.) and 6 by an engineer of the United States Geological Survey, and is well defined below and extended above 1,000 second-feet. Rating curve used January 1 to February 10 for staff gage at beach fairly well defined. Operation of water-stage recorder satisfactory except for July 1–8, when gage clock was run down; gage-height graph August 6 to October 8 lost, when skiff capsized with G. H. Canfield, October 8. Discharge record January 1 to February 10 computed from gage-height record for staff gage at beach. Daily discharge May 23 to August 5 ascertained by applying to rating table daily gage height determined by inspecting gage-height graph, or for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day.

Crater Lake is 1,010 feet above sea level and covers 1.1 square miles. The sides of the mountains surrounding the lake are steep and barren, and the tops are covered by glaciers.

Discharge measurements of Crater Lake outlet at Speel River, Port Snettisham, during 1918.

[Made by G. H. Canfield.]

Date.		Gage height.	Discharge.	Date.		Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 11		[a]1.22	127	Apr. 9		[a].74	32
Feb. 16		[a].58	10.1	Dec. 4			14.6

[a] Referred to staff gage at beach, installed Nov. 13, 1918.

Daily discharge, in second-feet, of Crater Lake outlet at Speel River, Port Snettisham, for 1919.

Day.	Jan.	Feb.	May.	June.	July.	Aug.	Oct.	Nov.
1	32	35	....	105	272	532	....	93
2	136	35	....	120	265	472	....	83
3	82	20	....	150	261	420	....	78
4	62	18	....	156	272	416	....	69
5	78	15	....	146	304	472	....	....
6	82	13	....	129	362	....	....	....
7	200	9	....	126	502	....	....	....
8	175	7	....	129	487	....	....	....
9	165	7	....	142	443	....	402	....
10	146	10	....	174	472	....	298	....
11	127	8	....	205	457	....	221	32
12	104	7	....	221	416	....	189	31
13	74	5	....	214	472	....	161	30
14	58	9	....	200	532	....	139	36
15	55	13	....	191	502	....	122	42
16	48	10	....	189	402	....	113	87
17	44	....	....	198	338	....	112	103
18	41	....	....	200	316	....	118	293
19	35	....	....	207	316	....	164	350
20	35	....	....	237	327	....	356	327
21	35	....	....	304	375	....	422	362
22	32	....	....	304	375	....	304	251
23	32	....	126	304	375	....	212	178
24	26	....	120	304	375	....	161	132
25	29	....	142	304	350	....	134	108
26	29	....	145	316	375	....	116	92
27	29	....	126	350	429	....	113	....
28	29	....	112	316	547	....	111	....
29	35	....	103	282	675	....	102	....
30	34	....	100	275	728	....	101	....
31	32	....	100	....	610	....	98	....

NOTE.—Discharge for following periods, for which gage-height records are not available, estimated from records for Sweetheart Falls Creek: Jan. 10, 20, 30, and Feb. 11, daily discharge: Feb. 17–28, 15 second-feet; Mar. 1–31, 12 second-feet; Apr. 1–30, 47 second-feet; May 1–22, 118 second-feet: July 1–8, daily discharge; Aug. 6–31, 520 second-feet; Sept. 1–30, 420 second-feet; Oct. 1–8, 470 second-feet; Nov. 5–10, 25 second-feet; Nov. 27–30, 25 second-feet; and Dec. 1–31, 30 second-feet.

Monthly discharge of Crater Lake outlet at Speel River, Port Snettisham, for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	200	26	68.4	4,210
February	35	5	14.6	811
March	....	....	12	738
April	....	....	47	2,800
May	....	....	118	7,260
June	350	105	217	12,900
July	728	261	417	25,600
August	....	....	511	31,400
September	....	....	420	25,000
October	....	98	259	15,900
November	362	....	101	6,010
December	....	....	30	1,840
The year	....	5	....	134,000

LONG RIVER BELOW SECOND LAKE, AT PORT SNETTISHAM.

Location.—One-half mile downstream from outlet of Second Lake, 1 mile downstream from outlet of Long Lake, one-half mile upstream from head of Indian Lake, 2½ miles by trail and boat across Second Lake from cabins of the Speel River project at head of the North Arm of Port Snettisham, 42 miles by water from Juneau.

Drainage area.—33.2 square miles (measured on sheet No. 12 of the Alaska Boundary Tribunal maps, edition of 1895).

Records available.—November 11, 1915, to December 31, 1919.

Gage.—Stevens continuous water-stage recorder on right bank one-half mile below outlet of Second Lake.

Discharge measurements.—At medium and high stages made from cable across river at gage; at low stages made by wading one-fourth mile downstream.

Channel and control.—At the gage the channel is deep and the current sluggish; banks are low and are overflowed at extremely high stages; bed smooth except for one large boulder. A rapid, 500 feet downstream, forms a well-defined and permanent control.

Extremes of discharge.—Maximum stage during year probably occurred October 6, but stage is unknown as gage-height graph July 9 to October 8 was lost; minimum flow 35 second-feet, March 29.

1916–1918: Maximum stage, 10.2 feet September 27, 1918 (discharge, estimated from extension of rating curve, 5,300 second-feet); minimum flow, 23 second-feet, February 13, 1916.

Ice.—Stage-discharge relation affected by ice during January, February, March, and April.

Accuracy.—Stage-discharge relation permanent; affected by ice or poor connection between well and river January 16 to February 27, March 6 to April 2, April 9–15, November 1–14, and December 4. Rating curve fairly well defined between 50 and 400 second-feet and well defined between 400 and 2,000 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Gage-height graph July 9 to October 8, lost on October 8, when skiff capsized with G. H. Canfield. Daily discharge ascertained by applying to the rating table daily gage height determined by inspecting the gage-height graph. Records good except for stages below 400 second-feet and periods of break in gage-height record, for which they are roughly approximate.

The area draining to Long River between Long Lake outlet and this station comprises only 1.3 square miles, including First Lake and Second Lake. Because this area is at a low altitude and has no glaciers the run-off per square mile from it is greater early in the spring but much less in summer than that from the area above Long Lake, which is partly covered by glaciers.

Discharge measurements of Long River below Second Lake, at Port Snettisham, during 1919.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan 10	2.40	345	July 8	4.03	920
Apr. 9	[a]1.74	88	Dec. 4	1.00	63

[a] Stage of water surface in well; connection between well and river obstructed.

Daily discharge, in second-feet, of Long River below Second Lake, at Port Snettisham, for 1919.

Day.	Jan.	May.	June.	July.	Oct.	Nov.	Dec.
1	100		317	630		125	76
2	230		360	600		115	70
3	280		411	565		106	66
4	175		411	630		95	63
5	260		390	720		85	
6	500		360	900		80	
7	670		360	1,070		75	
8	720		372	970		72	
9	550		405		975	70	
10	345		474		660	68	
11	351		530		495	65	
12	252		548		405	62	
13	198		548		317	80	
14	171		512		257	130	
15	146		495		207	211	
16			495		186	317	
17			512		190	339	
18			512		252	495	
19			530		301	505	
20			600		520	530	
21			680		660	565	
22		420	700		480	414	
23		390	720		345	290	
24		366	720		259		141
25		411	710		204		267
26		405	770		171		290
27		360	820		170		239
28		331	750		232		185
29		309	680		175		150
30		290	650		149		130
31		304			141		115

NOTE.—Owing to ice effect or obstruction in connection between gage well and river, discharge was estimated for following periods from current-meter measurement of Apr. 9 and comparison with weather records for Juneau and hydrograph of Sweetheart Falls Creek: Jan. 1–9, daily discharge shown in table Jan. 16–31, 95 second-feet; Feb. 1–28, 55 second-feet; Mar. 1–31, 50 second-feet; Apr. 1–30, 125 second-feet May 1–21, 285 second-feet. Daily discharge, June 25 to July 7 determined from gage-height graph drawn through maximum amd minimum stages shown by recorder and by comparison with graph for Sweetheart Falls Creek. Discharge for following periods estimated from records for Sweetheart Falls Creek owing to loss of gage-height record: July 9–31, 900 second-feet; Aug. 1–31, 1,050 second-feet; Sept. 1–30, 1,000 second-feet; Oct. 1–8, 1,070 second-feet. Daily discharge Nov. 1–14, Dec. 1–3, and mean discharge Nov. 24–30 (125 second-feet) estimated from records for Sweetheart Falls Creek. Mean discharge, Dec. 5–23 (115 second-feet), and daily discharge, Dec. 28–31, estimated from maximum and minimum stages shown by recorder and by comparison with records for Sweetheart Falls Creek.

Monthly discharge of Long River below Second Lake, at Port Snettisham, for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	720		209	12,900
February			55	3,050
March			50	3,070
April			125	7,440
May			309	19,000
June	820	317	545	32,400
July			864	53,100
August			1,050	64,600
September			1,000	59,500
October		141	526	32,300
November	565	62	192	11,400
December		63	128	7,870
The year			424	307,000

GRINDSTONE CREEK AT TAKU INLET.

LOCATION.—On north shore of Taku Inlet, between Point Bishop and Point Salisbury, one-fourth mile west of mouth of Rhine Creek and 11 miles by waterfrom Juneau.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 6, 1916, to December 31, 1919.

GAGE.—Stevens continuous water-stage recorder on left bank, 200 feet from tidewater, installed September 16, 1916. A Lietz seven-day graph water-stage recorder was used May 6 to June 17, 1916.

DISCHARGE MEASUREMENTS.—At all stages made by wading either in the channel on the beach, which is exposed at low tide, or 100 feet below gage at high tide.

CHANNEL AND CONTROL.—For a distance of one-fourth mile from tidewater the stream descends in a series of rapids and falls through a narrow, rocky channel. The gage is at upper end of a turbulent pool between two falls, the lower of which forms a well-defined control. When gage was installed logs were jammed in channel near upper end of pool.

EXTREMES OF DISCHARGE.—Maximum stage during year, from water-stage recorder, 4.2 feet at 5 p. m. October 3 (discharge, estimated from extension of rating curve, 330 second-feet); minimum discharge, 3 second-feet March 16–20, estimated by comparison with climatic data.

1916–1919: Maximum stage, 6 feet at 7 p. m. September 26, 1918 (discharge, estimated from an extension of the rating curve, 700 second-feet); minimum stage, −0.24 foot April 5–7, 1918 (discharge, 2.6 second-feet).

ICE.—Stage-discharge relation sometimes affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve, revised by measurements made during 1919, well defined below 150 second-feet; extended above 150 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods shown in the footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records good except those for periods of break in record and discharge above 150 second-feet, which are poor.

Discharge measurements of Grindstone Creek at Taku Inlet during the year ending Sept. 30, 1918.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 20	[a] 0.59	11.6	Apr. 22	0.59	16.0
23	[a] .43	11.0	July 7	1.71	114
Feb. 21	.15	6.1	Dec. 13	[b] .40	10.6
Mar. 22	−.05	3.8			

[a] Control partly obstructed by ice. [b] Ice cover arched over control; no backwater.

Daily discharge, in second-feet, of Grindstone Creek at Taku Inlet for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	17	10	3.5	......	19	29	47	52	35	40	19	13
2	25	9.5	3.5	......	18	41	45	47	30	85	18	15
3	19	9.0	3.0	......	17	61	67	46	26	184	17	15
4	17	9.0	3.0	......	17	64	69	48	24	130	......	13
5	19	8.0	3.0	......	17	55	73	50	24	260	......	12
6	45	7.5	3.5	......	18	48	128	46	22	189	......	12
7	40	8.0	4.0	......	19	42	130	40	22	124	......	......
8	56	8.0	3.5	......	26	39	92	71	21	87	......	......
9	38	7.5	3.0	......	34	44	92	67	48	70	......	......
10	30	7.5	3.5	......	30	59	89	48	60	60	......	......
11	28	7.5	3.5	......	28	64	80	43	34	51	......	......
12	24	7.0	3.5	......	32	56	74	39	34	45	......	......
13	20	7.0	3.5	......	31	55	79	41	116	41	......	11
14	18	7.0	3.5	......	36	52	83	57	69	36	......	10
15	17	7.0	3.5	......	44	49	71	50	50	32	......	8.0
16	16	7.0	3.0	......	48	49	61	51	43	33	......	9.5
17	14	7.0	3.0	......	43	51	57	43	......	28	......	22
18	11	7.5	3.0	......	44	50	70	43	......	38	......	34
19	11	8.0	3.0	......	48	51	62	85	......	48	......	16
20	12	7.5	3.0	......	48	70	62	79	......	48	......	14
21	12	7.0	3.5	......	41	71	60	54	......	43	......	13
22	14	6.5	4.0	17	38	66	54	45	......	32	28	13
23	11	5.5	......	18	34	59	52	37	......	28	23	15
24	11	5.0	......	19	37	53	49	34	......	25	18	16
25	11	4.5	......	30	38	54	45	31	......	24	17	18
26	11	4.0	......	52	36	70	51	28	80	23	17	27
27	11	3.5	......	43	32	71	59	43	64	27	18	19
28	10	3.5	......	34	29	61	64	38	60	24	16	16
29	10	......	......	26	28	54	74	61	52	22	15	15
30	10	......	......	24	28	49	70	52	45	22	14	16
31	10	......	......	......	29	......	57	43	......	21	......	16

NOTE.—Discharge for following periods estimated by comparison with records of flow for other stations, because stage-discharge relation was affected by ice: Jan. 19–25, Feb. 25–28, and Mar. 1–21, as shown in table. Operation of water-stage recorder not satisfactory for following periods, discharge estimated from maximum and minimum stages indicated by recorder and by comparison with records of flow for other stations: Mar. 22–31, 5 second-feet; Apr. 1–21, 15 second-feet; Sept. 17–25, 120 second-feet; Nov. 4–21, 25 second-feet; and Dec. 7–12, 11 second-feet.

Monthly discharge of Grindstone Creek at Taku Inlet for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	56	10	19.3	1,190
February	10	3.5	7.00	389
March	....	3.0	3.82	235
April	52	....	19.3	1,150
May	48	17	31.8	1,960
June	71	29	54.6	3,250
July	130	45	69.9	4,300
August	85	28	48.8	3,000
September	....	21	68.0	4,050
October	260	21	61.9	3,810
November	....	14	22.3	1,330
December	34	8.0	14.7	904
The year	260	3.0	35.3	25,600

CARLSON CREEK AT SUNNY COVE.

LOCATION.—At Sunny Cove, on west shore of Taku Inlet, 20 miles by water from Juneau.

DRAINAGE AREA.—22.26 square miles (determined by engineering department of Alaska Gastineau Mining Co. from surveys made by that company).

RECORDS AVAILABLE.—July 18, 1916, to December 31, 1919.

GAGE.—Stevens water-stage recorder on left bank, 2 miles from tidewater; inspected several times a week by employees of Alaska Gastineau Mining Co.

DISCHARGE MEASUREMENTS.—At high stages, made from cable across river one-half mile downstream from gage; at medium and low stages, made by wading 500 feet upstream from gage.

CHANNEL AND CONTROL.—Above the gage the stream meanders in one main channel and several small channels through a flat, sandy basin about a mile long; just below the gage the channel contracts and the stream passes over rocky falls that form a well-defined and permanent control. The point of zero flow is at gage height −1.5 feet.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 6.75 feet at 4 p. m. September 13 (discharge, from extension of rating curve, 4,440 second-feet); minimum flow, estimated by comparison with record of flow for Sweetheart Falls, 15 second-feet, March 28.

1916–1919: Maximum stage, 8.1 feet at 2 p. m. September 26, 1918 (discharge, computed from extension of rating curve, 6,200 second-feet); minimum flow, estimated from climatic data and hydrographs for streams in near-by drainage basins, 10 second-feet, April 1–7, 1918.

ICE.—Stage-discharge relation affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 70 and 2,000 second-feet, extended below 70 second-feet to point of zero flow and above 2,000 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods of break in record as indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Records good except for stages below 70 second-feet and above 2,000 second-feet and for periods of break in record, for which they are fair.

Discharge measurements of Carlson Creek at Sunny Cove during 1919.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 23		[a] 40	Apr. 22	−0.30	76
Feb. 21		[a] 24	Aug. 12	1.70	474
Mar. 22		[a] 20	Dec. 13		[a] 33

[a] Creek covered with thick ice. Measurement made 2 miles below gage; measured discharge reduced 5 per cent to obtain flow at gage.

Daily discharge, in second-feet, of Carlson Creek at Sunny Cove for 1919.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Dec.
1	....	367	605	590	175	104	....
2	....	399	560	560	137	288	....
3	....	530	658	545	120	1,100	....
4	....	455	....	658	108	1,080	....
5	....	387	....	762	102	1,860	....
6	....	370	....	590	108	3,160	....
7	....	419	....	530	127	1,270	....
8	....	425	....	658	128	441	....
9	....	500	....	840	452	272	....
10	....	622	....	622	1,020	182	....
11	....	640	....	530	362	124	....
12	....	575	....	470	485	114	....
13	....	605	....	581	3,150	107	33
14	....	545	....	1,450	999	107	....
15	....	530	....	885	470	104	....
16	....	515	....	860	282	101	....
17	....	575	....	622	1,040	104	....
18	....	545	....	622	1,210	136	....
19	....	575	....	1,510	540	266	....
20	....	710	....	902	440	455	....
21	....	780	....	500	2,030	455	....
22	....	710	....	359	662	156	....
23	....	675	....	300	636	102	....
24	340	728	575	272	1,460	....	....
25	545	762	590	263	1,170	....	....
26	402	762	675	250	396	....	....
27	315	745	820	382	210	....	....
28	277	692	950	590	115	....	....
29	268	675	1,020	745	156	....	....
30	292	605	745	500	106	....	....
31	326	....	622	272	....	....	....

NOTE.—Operation of water-stage recorder unsatisfactory and discharge for following periods estimated from four current-meter measurements, weather records, and hydrographs for other stations: Jan. 1-31, 137 second-feet; Feb. 1-28, 28 second-feet; Mar. 1-31, 20 second-feet; Apr. 1-23, 65 second-feet: Apr. 24-30, 200 second-feet; and May 1-23, 320 second-feet. July 4-23, estimated at 675 second-feet by comparison with record of flow for Sweetheart Falls Creek. Discharge for following periods estimated by comparison with records for other stations: Oct. 20-23, daily discharge; Oct. 24-31, 85 second-feet; Nov. 1-30, 130 second-feet; Dec. 1-12, 45 second-feet; Dec. 14-31, 150 second-feet.

Monthly discharge of Carlson Creek at Sunny Cove for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	....	....	137	8,420
February	....	....	28	1,560
March	....	....	20	1,230
April	....	....	96.5	5,740
May	....	....	327	20,100
June	780	367	581	34,600
July	1,020	....	688	42,300
August	1,510	250	620	38,100
September	3,150	102	617	36,700
October	3,160	....	412	25,300
November	....	....	130	7,740
December	....	....	106	6,520
The year	....	....	....	228,000

SHEEP CREEK NEAR THANE.

LOCATION.—At lower end of flat basin, above diversion dam for flume leading to Treadwell power house at beach and 1 mile by tramway and ore railway from Thane.

DRAINAGE AREA.—4.57 square miles above gaging bridge (measured on United States Geological Survey map of Juneau and vicinity, edition of 1917).

RECORDS AVAILABLE.—July 26, 1916, to December 31, 1919.

GAGE.—Stevens water-stage recorder on right bank, at pool formed by an artificial control just below small island three-tenths mile upstream from diversion dam. Recorder inspected once a week by an employee of the Alaska Gastineau Mining Co.

DISCHARGE MEASUREMENTS.—At extremely high stages, made from gaging bridge two-tenths mile downstream from gage; at low stages, made by wading near bridge section. No streams enter between gage and measuring section, but seepage inflow ranges from a small amount to 10 per cent of total flow, the percentage of inflow usually being large after periods of heavy precipitation.

CHANNEL AND CONTROL.—The station is near the lower end of a flat basin through which the stream meanders in a channel having low banks and a bed of sand and gravel. An artificial control was built 2 feet below the intake for the gage well, to confine the flow in one channel during high water and to insure a permanent stage-discharge relation. The spillway of the control at low stages consists of a timber, 16 feet long, set in the bed of the stream. During medium and high stages another timber, 8 feet long, bolted at the top near the right end, forms part of the control. A 3-foot cut-off wall is driven at the upstream face of the spillway. There are wing walls at each end, and an 8-foot apron extends downstream from the control.

ICE.—Control covered with ice and snow for short period.

EXTREMES OF DISCHARGE.—Maximum stage during year, 2.52 feet, at 1 a. m. October 6 (discharge, estimated from extension of rating curve, 490 second-feet); minimum stage, −0.48 foot March 31 to April 2 (discharge, 4.0 second-feet).

1916–1919: Maximum stage during period, 3.5 feet, at 2 p. m. September 26, 1918 (discharge, estimated from extension of rating curve, 820 second-feet); minimum flow, 1.0 second-foot, April 6–8, 1917.

ACCURACY.—Stage-discharge relation, between 0.5 and 1.2 feet, changed January 8. Rating curve used January 1–8, fairly well defined below 700 second-feet; curve used January 9 to December 31 fairly well defined. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Records fair.

Discharge measurements of Sheep Creek near Thane during 1919.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 25	0.66	18	July 1	1.00	74
Feb. 11	.30	9.0	Aug. 20	1.135	105
Mar. 20	−.40	4.5	Oct. 22	.86	43
Apr. 17	.65	16	Dec. 11	.53	13
May 13	.92	52			

Daily discharge, in second-feet, of Sheep Creek near Thane for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	22	13	6.5	4.0	41	61	72	72	41	46	19	......
2	22	11	6.4	4.0	35	......	72	63	36	72	18	......
3	21	9.3	6.3	4.9	32	......	96	61	35	210	17	......
4	19	9.2	6.2	5.9	31	72	108	68	34	164	17	......
5	16	9.0	6.0	7.0	30	70	108	72	34	322	16	......
6	38	8.5	......	8.3	30	84	124	68	32	379	15	......
7	68	8.4	......	9.0	34	88	134	61	34	232	15	......
8	75	8.3	......	12	50	......	108	72	34	146	15	......
9	63	8.1	......	15	61	......	108	91	68	111	14	......
10	54	8.0	......	16	52	......	115	77	103	91	14	......
11	48	7.9	......	16	50	......	108	70	54	......	14	13
12	46	7.8	......	16	52	......	105	63	56	......	13	13
13	41	7.7	......	16	54	......	113	72	244	......	13	12
14	38	7.6	......	17	63	......	115	113	121	......	13	12
15	35	7.5	......	18	86	......	103	96	88	......	19	12
16	31	7.3	......	18	91	......	91	96	72	......	......	12
17	27	7.2	......	17	79	......	88	77	96	......	......	15
18	23	7.1	......	18	82	......	94	72	98	......	......	25
19	21	7.1	......	18	96	......	91	141	84	......	......	15
20	19	7.0	4.5	19	96	......	88	113	79	......	......	16
21	19	6.9	4.5	22	84	......	86	88	251	......	68	16
22	19	6.8	4.4	22	77	......	82	77	113	43	52	16
23	19	6.7	4.4	25	72	......	79	68	108	40	38	15
24	18	6.6	4.3	23	72	......	77	61	252	40	25	15
25	18	6.6	4.3	61	84	......	77	59	176	36	......	19
26	18	6.6	4.2	84	77	......	77	52	121	34	......	35
27	17	6.6	4.2	86	68	......	86	63	94	34	......	26
28	16	6.6	4.1	68	61	......	96	68	72	32	......	22
29	16	......	4.1	59	54	......	108	88	68	27	......	19
30	16	......	4.0	50	54	......	98	68	56	26	......	17
31	15	......	4.0	......	54	......	79	54	......	23	......	18

NOTE.—Daily discharge Jan. 10–24 and Mar. 1–5 estimated, because of unsatisfactory operating of gage by comparison with records for Gold Creek. Discharge for following periods estimated from maximum and minimum stages shown by gage and comparison with records of flow for Gold Creek: Mar. 6–19, 5 second-feet; June 2–3, 80 second-feet; June 8–30, 90 second-feet; Oct. 11–21, 53 second-feet; Nov. 16–20, 60 second-feet; Nov. 25–30, 22 second-feet; Dec. 1–10, 18 second-feet; Dec. 30 and 31 as shown in table.

Monthly discharge of Sheep Creek near Thane for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	75	15	29.6	1,820
February	13	6.6	7.87	437
March	......	......	4.92	303
April	86	4.0	25.3	1,510
May	96	30	61.4	3,780
June	......	......	86.8	5,160
July	134	72	96.3	5,920
August	141	52	76.3	4,690
September	252	32	91.8	5,460
October	379	23	86.8	5,340
November	......	13	28.2	1,680
December	35	......	17.5	1,080
The year	379	......	51.3	37,200

GOLD CREEK AT JUNEAU.

LOCATION.—At highway bridge at lower end of Last Chance basin, 200 feet upstream from diversion dam of Alaska Electric Light & Power Co. and one-fourth mile from Juneau.

DRAINAGE AREA.—9.47 square miles (determined by engineering department of Alaska Gastineau Mining Co. from surveys made by that company).

RECORDS AVAILABLE.—July 20, 1916, to December 31, 1919.

GAGE.—Stevens continuous water-stage recorder on left bank at upstream side of highway bridge. A staff gage was installed September 19, 1916, on left wing wall of diversion dam 200 feet downstream and used in determining the time of changes in stage-discharge relation at the well gage.

DISCHARGE MEASUREMENTS.—At medium and high stages made from gaging bridge suspended, at right angles to current, from floor of highway bridge; at low stages, made by wading near gage.

CHANNEL AND CONTROL.—Station is at lower end of a flat gravel basin three-fourths mile long. For 20 feet upstream from gage the stream is confined between the abutments of an old bridge, and for 15 feet downstream it is confined between the abutments of present bridge. For a distance of 130 feet farther downstream the stream is confined in a narrow channel which is not subject to overflow. Because of the steep gradient of channel opposite and for 150 feet below gage, a short stretch of the channel immediately below the gage acts as the control. The operation of the headgates of flume at diversion dam, 200 feet downstream, does not affect the stage-discharge relation at gage, but the swift current during high stages shifts the gravel in bed of stream, thereby causing changes in the stage-discharge relation.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 4.9 feet at 2 p. m., September 13 (discharge, computed from extension of rating curve, 1,300 second-feet); minimum flow, estimated by discharge measurements and climatic data, 2 second-feet, March 15–28.

1916–1919: Maximum stage, 6.8 feet September 26, 1918 (discharge estimated from extension of rating curve, 2,600 second-feet); minimum discharge, 0.9 second-foot March 26, 1918.

ICE.—Stage-discharge relation affected by ice in February, March, and April.

DIVERSION.—Water diverted at several points upstream for power development is returned to creek above gage, except about 20 second-feet for seven months (when there is a surplus over amount used by Alaska Electric Light & Power Co., which has prior right) and 1 second-foot the remainder of year, used by the Alaska-Juneau Gold Mining Co. A dam 200 feet downstream diverts water into the flume of the Alaska Electric Light & Power Co.

REGULATION.—No storage or diversions above station regulate the flow more than a few hours in low water.

ACCURACY.—Stage-discharge relation changed during periods of high water; 13 discharge measurements were made during year, by use of which rating curves have been constructed applicable as follows: January 1 to June 21, well defined below and fairly well defined above 70 second-feet; June 22 to September 13, fairly well defined; September 14–24 (a. m.), poorly defined by one discharge measurement; September 24 (p. m.) to November 17, fairly well defined by two discharge measurements; November 18 to December 31, fairly well defined by two discharge measurements. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuations, by averaging results obtained by applying to rating table mean gage heights for equal intervals of the day. Records fair.

Discharge measurements of Gold Creek at Juneau during 1919.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 24	0.89	14.5	May 10	1.37	59	Nov. 19	1.35	116
Feb. 10	.78	10.5	July 1	1.88	162	28	.71	24
Mar. 14	[a] .70	2.1	Aug. 6	1.86	151	Dec. 27	.92	46
Apr. 4	[a] .98	17.0	Sept. 15	2.16	173			
18	.92	14.6	Oct. 15	1.08	46			

[a] Control and measuring section frozen over.

Daily discharge, in second-feet, of Gold Creek at Juneau for 1919.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	16	12			48	88	158	167	78	42	16	20
2	22	11			39	109	153	147	70	98	15	21
3	19	11			32	137	231	140	63	410	14	20
4	18	11			27	118	270	169	63	320	14	19
5	20	10			22	109	255	198	63	615	14	19
6	45	10				96	300	158	63	725	13	19
7	71	10				96	330	132	70	304	13	17
8	86	10				97	246	174	70	114	13	16
9	62	10				114	270	216	151	73	13	14
10	55	10			59	147	285	180	240	50	12	14
11	46				55	158	285	102	111	47	12	12
12	34				62	161	264	141	147	39	12	12
13	31				62	170	309	162	920	35	20	12
14	27				77	143	340	285	295	30	18	12
15	25				118	137	276	228	188	46	18	12
16	21				137	143	208	202	165	30	18	16
17	19				109	147	185	162	289	37	46	41
18	19				109	137	216	174	273	32	230	72
19	19				147	161	210	365	154	42	125	33
20	19				152	215	198	285	135	57	134	22
21	16				118	240	205	174	490	98	99	19
22	14				99	225	195	140	183	73	63	17
23	14				99	210	195	130	172	42	45	25
24	14				106	210	180	130	470	32	30	42
25	14				122	210	162	130	320	30	29	53
26	14				102	222	198	115	165	28	30	93
27	14				84	225	225	158	109	31	29	49
28	13				77	198	255	174	93	26	27	36
29	13				72	180	300	198	91	22	25	29
30	13				71	167	255	140	60	21	22	25
31	12				77		190	115		20		27

NOTE.—Water-stage record lost for following periods; discharge estimated from three discharge measurements, from climatic records for Juneau, and by comparison with hydrographs or other stations: Feb. 11-28, 9 second-feet; Mar. 1-31, 5 second-feet; and Apr. 1-30, 35 second-feet. Operation of water-stage recorder unsatisfactory for following periods, discharge estimated by comparison with records for Sheep Creek: May 6-9, 50 second-feet; Aug. 11-20, as shown in table.

Monthly discharge of Gold Creek at Juneau for 1919.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	86	12	26.6	1,640
February			9.54	530
March			5	307
April			35	2,080
May	152	22	79.8	4,910
June	210	88	159	9,460
July	310	153	237	14,600
August	365	115	176	10,800
September	490	60	192	11,400
October	725	20	115	7,070
November	230	12	39.0	2,320
December	93	12	27.0	1,660
The year	725		92.2	66,800

FALLS CREEK AT NICKEL, NEAR CHICHAGOF.

LOCATION.—One-eighth mile above beach, on stream that enters tidewater half a mile northeast of camp of Alaska Nickel Mines Co., 20 miles by water northwes of Chichagof, on west coast of Chichagof Island.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 6, 1918, to December 31, 1919.

GAGE.—Stevens water-stage recorder on left bank one-eighth mile above beach.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from cable across stream 500 feet above gage; at low stages, made by wading in channel exposed at beach at low tide.

CHANNEL AND CONTROL.—The gage is 20 feet upstream from rectangular weir, the crest of which is 2 feet above bed of stream, 2 inches wide, and 40 feet long. At the cable section the bed is smooth, the water is deep, and the current is regular and sluggish.

EXTREMES OF STAGE.—Maximum stage recorded during period, 3.45 feet at 3 p. m. September 26, 1918; minimum stage recorded, 0.18 foot March 12, 1919.

ICE.—Stage-discharge relation affected by ice forming on crest of weir.

ACCURACY.—Stage-discharge relation permanent; affected by ice January 18, February 25 to March 4, 1918. Sufficient discharge measurements not yet available to define rating curve. Operation of water-stage recorder satisfactory except for following periods; November 24–30, December 29, 1918, January 18, to February 8, March 23 to April 3, April 28 to May 3, May 4 to 17, July 22–27, August 11–15, September 24, and December 17–27, 1919. Mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging mean gage heights for regular intervals of the day.

COOPERATION.—The gage and weir were installed by the Alaska Nickel Mines Co., and the cable and car by the United States Geological Survey in cooperation with the company which also furnished the gage-height record and most of the discharge measurements.

Discharge measurements of Falls Creek at Nickel during 1918–19.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1918.		*Feet.*	*Sec.-ft.*	1919.		*Feet.*	*Sec.-ft.*
June 10	G. H. Canfield	0.92	90	Jan. 19	Kimball	[b] 0.70	23
11	....do	.96	100	Feb. 21	....do	[b] .44	24
July 8	F. S. Fleming [a]	.52	38				
Dec. 30	Kimball [a]	.56	48				

[a] Employee of Alaska Nickel Mines Co.
[b] Stage-discharge relation affected by ice.

Daily gage height, in feet, of Falls Creek at Nickel for 1918–19.

Day	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918.								
1	....	1.07	1.01	0.59	1.60	0.62	1.15	1.70
2	....	.94	.86	.55	1.10	.60	.89	1.42
3	....	.86	.77	.51	.70	.76	.73	1.07
4	....	.81	.71	.48	.55	.78	.87	.87
5	....	.81	.65	.46	.50	.69	2.70	.79
6	1.10	.84	.59	.53	.45	.62	2.25	.98
7	.92	.91	.56	.67	.43	.67	1.48	.70
8	.87	.99	.54	.60	.40	.60	1.07	.61
9	....	1.00	.52	.68	.83	.65	.84	.57
10	.87	.93	.49	.53	.68	.52	.70	.52
11	.94	.95	.66	.50	.60	.50	.73	.48
12	.98	.93	.68	.48	.55	.95	.88	.45
13	.98	.87	.60	.62	.52	.87	.75	.42
14	.97	.83	.55	.97	.48	1.10	.70	.43
15	.92	.81	.51	.75	.60	.88	.60	.41
16	.88	.75	.48	.75	.70	.75	.59	.67
17	.82	.70	.46	.92	1.39	.88	.54	.73
18	.83	.67	.44	.78	1.70	.98	.46	.68
19	.77	.63	.42	.75	1.30	.80	.43	.62
20	.70	.67	.42	.78	.97	.78	.57	.54
21	.75	.65	.40	1.03	.78	.72	.75	1.23
22	.70	.61	.38	1.20	.65	.62	.83	1.20
23	.70	.60	.37	1.33	.93	.59	.85	1.30
24	.70	.66	.37	1.61	.75	.65	....	1.08
25	.73	.71	.36	1.43	1.36	.62	....	1.16
26	.76	.73	.35	1.15	2.48	1.07	....	1.07
27	.77	.75	.46	1.00	1.87	.88	....	.85
28	1.54	.75	.63	1.26	1.27	1.30	....	.70
29	1.81	1.07	.50	1.30	.95	1.18	....	....
30	1.51	1.33	.55	2.24	.73	1.28	....	.56
31	1.34	....	.66	2.46	....	1.20	....	.52

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1919.												
1	0.57	......	0.76	......	......	0.61	0.45	0.36	0.78	0.58	0.63	0.39
2	1.07	......	.68	......	......	.66	.44	.35	.62	1.73	.51	.36
3	.90	......	.63	......	......	.69	.48	.34	.54	2.6	.46	.36
4	.82	......	.56	0.71	0.53	.67	.52	.34	.48	2.3	.43	.37
5	.92	......	.26	.75	......	.66	.52	.42	.42	2.3	.38	.45
6	1.64	......	.30	.75	......	.65	.63	.37	.39	2.8	.35	.65
7	1.57	......	.31	.68	......	.62	.60	.35	.38	2.00	.33	.49
8	1.45	......	.38	.65	......	.58	.57	.55	.36	1.32	.40	.47
9	1.15	0.37	.45	.64	......	.58	.60	.75	1.02	.95	.33	.70
10	.96	.45	.37	.57	......	.57	.76	.65	1.05	.94	.30	.72
11	.86	.37	.33	.55	......	.57	.78	......	.80	.77	.30	.60
12	.71	.34	.23	.52	......	.57	.76	......	1.48	.68	.33	.50
13	.65	.35	.35	.52	......	.60	.88	......	2.73	.64	.64	.44
14	.60	.39	.55	.52	......	.62	.88	......	1.95	.56	.52	.34
15	.52	.38	.65	.49	......	.62	.76	......	1.25	.50	.67	.55
16	.48	.36	.70	.46	......	.58	.66	.78	1.00	.55	.71	1.12
17	.82	.37	.67	.59	......	.56	.62	.70	1.28	.53	1.00	......
18	......	.62	.68	.67	.81	.55	.63	.80	1.40	.72	1.54	......
19	......	.66	.57	.75	.96	.56	.59	1.20	1.05	.70	1.34	......
20	......	.52	.80	.75	1.24	.60	.61	1.15	.93	1.29	1.50	......
21	......	.46	1.07	.72	1.04	.60	.63	.85	1.65	1.16	1.09	......
22	......	.45	.81	.66	.89	.60	......	.70	1.19	.88	.87	......
23	......	.39	......	.74	.78	.60	......	.60	1.08	.72	.70	......
24	......	.35	......	.71	.80	.58	......	.55	......	.64	.59	......
25	......	.34	......	1.41	.88	.56	......	.46	1.60	.57	.52	......
26	......	.29	......	1.68	.80	.53	......	.42	1.13	.59	.48	......
27	......	.45	......	1.65	.74	.51	......	.58	.85	.62	.46	......
28	......	.65	......	......	.74	.51	.40	.75	.85	.56	.45	.66
29	......	......	......	......	.69	.49	.37	1.02	.75	.57	.46	.60
30	......	......	......	......	.64	.47	.36	1.08	.66	1.10	.41	1.34
31	......	......	......	......	.61	......	.36	.98	......	.70	......	......

NOTE.—For following periods water-stage recorder did not operate satisfactorily, but maximum and minimum stages were recorded: Nov. 24–30, 1918: Maximum stage, 1.90 feet; minimum, 0.83 foot. Jan. 18 to Feb. 8: Maximum stage, 0.88 foot; minimum, 0.83 foot. Mar. 23 to Apr. 3: Maximum stage, 0.90 foot; minimum, 0.22 foot.

PORCUPINE CREEK NEAR NICKEL.

LOCATION.—Half a mile above beach, on stream that enters tidewater at head of Porcupine Harbor, 4 miles northwest of camp of Alaska Nickel Mines Co., which is 20 miles by water northwest of Chichagof, on west coast of Chichagof Island.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 20, 1918, to December 31, 1919.

GAGE.—Stevens water-stage recorder on left bank of stream half a mile above beach.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from cable across stream 150 feet above gage; at low stages, made by wading near control.

CHANNEL AND CONTROL.—The gage is located at edge of deep pool formed by contraction of channel where stream passes over exposed bedrock and descends in a series of small falls. The head of these falls forms a well-defined and permanent control. At the cable section the bed is rough, the water is deep, and the current is sluggish and irregular, because 15 feet above cable the stream widens into a small lake.

EXTREMES OF STAGE.—1918–19: Maximum stage recorded during period, 3.35 feet at 10 a. m. November 6, 1918; minimum stage recorded, 0.37 foot March 19 and 28, 1919.

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent, affected by ice only February 25. Sufficient discharge measurements not yet available to define rating curve. Operation of water-stage recorder satisfactory except for following periods: July 22 to August 4, November 30 to December 23, 1918, May 10–13, July 26–30, October 5–8, 24–31, and December 1–17, 1919. Mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging mean gage heights for regular intervals of the day.

COOPERATION.—The gage was installed by the Alaska Nickel Mines Co., and the cable and car by the United States Geological Survey in cooperation with the company, which also furnished gage-height graph and 4 discharge measurements.

Discharge measurements of Porcupine Creek near Nickel during 1918–19.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1918.		*Feet.*	*Sec.-ft.*	1919.		*Feet.*	*Sec.-ft.*
June 12	G. H. Canfield	1.60	140	Jan. 16	Kimball	1.30	112
Aug. 5	F. S. Fleming	.96	68	25	.....do	.94	69
				Mar. 1	.....do	.53	36

Daily gage height, in feet, of Porcupine Creek near Nickel for 1918–19.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918.								
1	......	1.88	1.59	......	2.35	1.70	1.83	......
2	......	1.78	1.54	......	2.05	1.60	1.73	......
3	......	1.70	1.50	......	1.84	1.62	1.60	......
4	......	1.64	1.45	......	1.69	1.62	1.53	......
5	......	1.59	1.40	0.96	1.57	1.55	2.47	......
6	......	1.59	1.35	.98	1.47	1.48	3.25	......
7	......	1.59	1.33	1.07	1.37	1.44	2.8	......
8	......	1.63	1.30	1.10	1.29	1.43	2.40	......
9	......	1.64	1.27	1.08	1.24	1.38	2.10	......
10	......	1.62	1.25	1.05	1.35	1.32	1.85	......
11	......	1.62	1.28	1.02	1.31	1.28	1.72	......
12	......	1.60	1.30	1.08	1.30	1.41	1.67	......
13	......	1.55	1.26	1.25	1.25	1.47	1.58	......
14	......	1.53	1.22	1.22	1.20	1.53	1.52	......
15	......	1.52	1.20	1.22	1.14	1.51	1.45	......
16	......	1.48	1.18	1.32	1.23	1.46	1.40	......
17	......	1.44	1.15	1.32	1.50	1.45	1.33	......
18	......	1.41	1.13	1.29	1.80	1.55	1.25	......
19	......	1.37	1.10	1.32	1.80	1.52	1.20	......
20	......	1.36	1.08	1.40	1.68	1.48	1.22	......
21	1.24	1.34	1.04	1.55	1.57	1.43	1.27	......
22	1.23	1.30	......	1.65	1.48	1.35	1.38	......
23	1.22	1.28	......	1.86	1.52	1.30	1.38	......
24	1.20	1.28	......	1.91	1.45	1.30	1.42	1.46
25	1.20	1.30	......	1.85	1.70	1.27	1.43	1.49
26	1.20	1.30	......	1.75	2.6	1.37	1.57	1.57
27	1.21	1.30	......	1.81	2.9	1.39	1.63	1.49
28	1.50	1.32	......	1.90	2.45	1.52	1.62	1.42
29	1.91	1.45	......	2.37	2.15	1.60	1.82	1.34
30	2.03	1.64	......	3.0	1.90	1.72	1.85	1.29
31	1.96	......	......	2.75	......	1.80	......	1.22

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1919.												
1	1.20	0.80	0.50	0.68	1.39	1.23	1.07	0.96	1.50	1.63	1.33	......
2	1.86	.77	.49	.71	1.33	1.28	1.04	.94	1.45	2.05	1.32	......
3	1.37	.75	.48	.74	1.28	1.25	1.04	.92	1.37	2.86	1.33	......
4	1.38	.73	.45	.73	1.23	1.22	1.07	.91	1.30	3.18	1.28	......
5	1.38	.70	.48	.78	1.21	1.20	1.07	.92	1.24	......	1.28	......
6	1.67	.68	.45	.81	1.21	1.18	1.09	.92	1.16	......	1.23	......
7	1.90	.67	.45	.81	1.22	1.16	1.13	.80	1.12	......	1.18	......
8	1.95	.65	.46	.81	1.23	1.14	1.13	.85	1.08	......	1.05	......
9	1.91	.65	.52	.81	1.26	1.12	1.14	.98	1.25	2.50	1.13	......
10	1.80	.67	.49	.80	......	1.12	1.17	1.00	1.40	2.28	1.11	......
11	1.71	.65	.47	.80	......	1.11	1.27	1.00	1.32	2.02	1.04	......
12	1.60	.63	.50	.81	......	1.11	1.28	.98	1.45	1.38	1.01	......
13	1.50	.61	.45	.81	1.21	1.10	1.34	1.08	2.75	1.69	1.09	......
14	1.45	.62	.43	.81	1.23	1.10	1.39	1.18	2.98	1.61	1.06	......
15	1.37	.62	.40	.80	1.29	1.11	1.38	1.16	2.52	1.54	1.11	......
16	1.29	.60	.40	.79	1.33	1.10	1.36	1.26	2.23	1.46	1.11	......
17	1.23	.57	.40	.81	1.31	1.10	1.33	1.23	2.15	1.40	1.24	......
18	1.16	.70	.39	.88	1.30	1.10	1.31	1.22	2.35	1.38	1.47	1.44
19	1.10	.75	.38	.88	1.35	1.10	1.28	1.43	2.15	1.37	1.60	1.39
20	1.05	.69	.42	.90	1.50	1.11	1.26	1.50	1.95	1.57	1.72	1.36
21	1.05	.66	.50	.92	1.50	1.13	1.26	1.46	2.35	1.71	1.70	1.36
22	1.03	.64	.46	.92	1.48	1.13	1.25	1.40	2.15	1.73	1.65	1.41
23	.98	.63	.45	.94	1.44	1.15	1.21	1.33	2.10	1.58	1.88	1.43
24	.95	.60	.44	.94	1.41	1.15	1.19	1.27	2.50	1.46	......	1.58
25	.94	1.44	.42	1.19	1.44	1.15	1.14	1.20	2.70	1.43	......	1.66
26	.87	.55	.40	1.37	1.42	1.13	......	1.16	2.35	1.32	......	1.81
27	.90	.53	.39	1.55	1.38	1.12	......	1.18	2.08	1.29	......	1.78
28	.88	.52	.38	1.54	1.34	1.11	......	1.25	1.96	1.27	......	1.69
29	.87	......	.41	1.49	1.32	1.11	......	1.36	1.88	1.24	......	1.61
30	.85	......	.46	1.44	1.26	1.09	......	1.50	1.70	1.44	......	1.51
31	.82	......	.61	......	1.22	......	.97	1.55	......	1.35	......	1.61

MISCELLANEOUS MEASUREMENTS.

Miscellaneous discharge measurements in southeastern Alaska in 1919.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
Apr. 11	Spruce Creek	Windham Bay	Mouth of creek	15.6
July 12	do	do	At bridge near mill of Alaska Peerless Gold Mining Co., half a mile above mouth of creek.	28.6

WATER POWER ON CERTAIN STREAMS IN SOUTHEASTERN ALASKA.

Owing to the great variation in flow of streams in southeastern Alaska, storage is an important factor in determining the power that can be developed and the cost of development. The amount of possible storage is generally estimated, because few local maps or sketches of river basins are available.

In the following table the estimates of annual flow at gaging stations are based on records prior to October 1, 1918. The flow at the point of diversion to the power plant is estimated from the records for gaging stations, by comparison with records for other streams, or from precipitation data. The "annual flow" is that for the climatic year ending September 30. The effective head is the elevation of the lake or dam site above high tide plus two-thirds of the head created by the dam minus 10 feet (elevation of nozzles of impulse turbines). The estimates of available power are based on continuous and complete utilization of a plant having an efficiency of 80 per cent.

The following abbreviations are used in the table:

A. B. S., Alaskan Boundary Survey maps.
U. S. G. S., U. S. Geological Survey topographic maps.
U. S. F. S., U. S. Forest Service topographic maps.
U. S. F. S. R., U. S. Forest Service timber reconnaissance maps.

Data concerning certain streams in southeastern Alaska on which power may be developed.

Stream and location.	Drainage area.	Map used.	Records available.	Mean annual flow. At gaging station.	Mean annual flow. At point of diversion.	Elevation of lake or dam site above high tide.	Storage required to equalize flow, or storage available.	Area of lake or basin.	Height of dam above or depth of tunnel below lake surface for obtaining required storage.	Length of conduit.	Mean static head.	Continuous horsepower at 80 per cent efficiency.
	Square miles.			*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Acre-feet.*	*Acres.*	*Feet.*	*Miles.*	*Feet.*	
Mainland:												
Endicott River on west shore of Lynn Canal (reconnaissance by Alaska Gastineau Mining Co., 1913; lake gone).			None			175	53,800 (50-foot dam 18 miles from beach).		250-foot dam for head only.		(a)	10,000
Small stream on west shore of Taiya Inlet; mouth of Skagway.	1.8	A. B. S.	do		11	3,000				1.75	3,000	3,000
Sherman Creek at Comet; on east side of Lynn Canal.	3.65	U. S. G. S.	September, 1914, to December, 1917.	31	34 (storage for only 7 sec.-ft.)	500	2,000		100	1	560	350
Davies Creek, Berners Bay.	16.0	U. S. G. S.	Measurement, Sept. 8, 1916.		145	200	40,000		150	1.7	290	4,000
Peterson Lake outlet near Eagle River Landing.	5.7	U. S. G. S.	None		40	650	10,000	85	50	(b)	675	3,000
Montana Creek at elevation 250 feet; tributary to Mendenhall River; power house at elevation 50 feet.	10.9	U. S. G. S.	do		110	250	30,000		150	3	300	3,000
Nugget Creek, Mendenhall Glacier.												[c] 3,500
Salmon Creek near Juneau.	[d] 5.34											[c] 6,000
Gold Creek at Juneau	[d] 9.47											[c] 1,000
Sheep Creek at Thane	[d] 4.57		July 26, 1916	52	41 (storage for only 30 sec.-ft.).	640	7,000	150 (at 710-foot contour).	70		680	2,000
Grindstone Creek at Taku Inlet.	[d] 3.0		May 6, 1911	41	32 (storage for about 20 sec.-ft.).	220						
Carlson Creek at Taku Inlet.	[d] 22.3		July 18, 1916	358	283 (storage for only 100 sec.-ft.).	350	20,000	300 (at 470-foot contour).			420	3,800
Annex Creek at Taku Inlet.	[e] 6.4											[h] 5,000

Norris Creek at Norris Glacier.	9.0	A. B. S.	None.		100	[e]350				2.5	400	3,600
Turner Lake Outlet, Taku Inlet.	66	A. B. S.	May, 1908, to April, 1909.	450	550	80	180,000	2,400	75	6	130	6,500
Carlson Lake outlet at Taku Harbor.			Measurement, Sept. 3, 1916.		8.6	[c]1,100			25			850
Crater Lake outlet at Port Snettisham.	11.9	A. B. S.	Jan. 23, 1913.	197	190	[f]1,012	54,000	700	Dam, 50; tunnel, 50.	.9	1,012	17,500
Long Lake outlet at Speel River.	33.2	A. B. S.	do.	75	465	[f]803	151,000	2,000	Dam, 50; tunnel, 35.		[g]515	22,000
Speel River at Port Snettisham.			July 15, 1916, to Sept. 30, 1918.	2,700	2,700 (storage for only 1,875 sec.-ft.).	[f]150	370,000 (above elev. 192 feet).		157		262	45,000
Tease Lake outlet at Port Snettisham.	10.3	A. B. S.			125	[f]1,010	35,000	240	Dam, 50; tunnel, 100.	1.1	1,000	11,500
Sweetheart Falls Creek at Port Snettisham.	27	A. B. S.	July 31, 1915, to Mar. 31, 1917; May 21, 1918.	319	325	[e]520	90,000	1,500	50	2	545	15,000
Stream entering salt lake at head of Hobart Bay.	40	A. B. S.	None.		Storage for only 160 second-feet.	250	45,000 (between 300 and 400 foot contours).		150	2	360	5,000
Below fork of stream entering head of Port Houghton.	73	A. B. S.	do.		Storage for only 300 second-feet.	50	50,000 at lake; 50,000 (between 100 and 200 foot contours).	440	Lower dam, 150 feet; dam at lake or storage only 50 feet.	125	165	5,400
Farragut River tributary to Farragut Bay; dam at lake on north fork, 12 miles from beach.			do.		Storage for only 125 second-feet.	250		500	100	12	[h]267	5,200
Cascade Creek, Thomas Bay.	21	A. B. S.	Oct. 27, 1917.	304	At dam site, 220 (storage for only 80 sec.-ft.).		10,500		150	1.95	1,090	12,300
Stream tributary to west shore of Thomas Bay; 1.4 miles north of West Point.	10	A. B. S.	Measurement, Aug. 9, 1917.		50	[e]400	11,000	300	40	1.25	416	1,900
Stream tributary to north shore of Bradfield Canal, 2 miles east of Blake Channel.	15.5	A. B. S.	None.		90	[i]150				2	[a]175	1,400

[a] Elevation of power house, 95 feet.
[b] Three miles to Pearl Harbor; 4,000 feet of tunnel and 1,300 feet of pipe line to Tee Harbor.
[c] Developed.
[d] Determined by Alaska Gastineau Mining Co.
[e] Elevation determined by aneroid barometer.
[f] Reported by Speel River Project (Inc.).
[g] Elevation of power house, 300 feet.
[h] Elevation of power house, 50 feet.
[i] Estimated.

Stream and location.	Drainage area.	Map used.	Records available.	Mean annual flow. At gaging station.	Mean annual flow. At point of diversion.	Elevation of lake or dam site above high tide.	Storage required to equalize flow, or storage available.	Area of lake or basin.	Height of dam above or depth of tunnel below lake surface for obtaining required storage.	Length of conduit.	Mean static head.	Continuous horsepower at 80 per cent efficiency.
	Square miles.			*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Acre-feet.*	*Acres.*	*Feet.*	*Miles.*	*Feet.*	
Mainland—Continued.												
Stream tributary to north shore of Bradfield Canal, 11 miles east of Blake Channel; three-fourths mile from beach.	80	A. B. S.	None		700	[a]50	200,000 (between 100 and 200 foot contours; estimated).	3,000 (at 250 foot contour).	150	4.5	165	10,000
Stream tributary to north shore of Bradfield Canal, 1 mile west of the head; 1 mile from beach.	42	A. B. S.	do		300	[a]75	80,000 (between 150 and 250 foot contours).	1,100 (at 250 foot contour).	175	.75	200	5,500
Stream tributary to south shore of Bradfield Canal, 1 mile west of the head.	14	A. B. S.	do		100	1,100	25,000	500	Dam, 25; tunnel, 25.	2	1,100	10,000
Stream tributary to south shore of Bradfield Canal, 11 miles east of Blake Channel; at lake 5 miles from beach.	36	A. B. S.	do		Storage for 250 second-feet.	[a]300	65,000	300	130	5	376	8,500
Stream entering south shore of Bradfield Canal, 2 miles east of entrance.	27	A. B. S.	do		150	[a]150	39,000		100	2	210	3,800
Stream tributary to east bank of Chickamin River, 4 miles upstream from mouth.	23	A. B. S.	do			[a]150				.5		
Shelockum Lake outlet, Bailey Bay.	18	A. B. S.	June 4, 1915	211	200	344	52,000	350	Dam, 60; tunnel, 100.		340	6,000
Revillagigedo Island:												
Orchard Lake outlet, Shrimp Bay.		U. S. F. S.	May 28, 1915	600	600	134	130,000	1,400	70		175	9,500
Mahoney Creek, George Inlet.		U.S.F.S.R.	Measurement, Sept. 13, 1917		At lake, 35; at beach, 58.	2,000	7,000	180	Tunnel, 60	.75	[b]1,890	6,000
Beaver Falls Creek, George Inlet, at Upper Lake outlet.	3.6		Three measurements in 1917.		55	1,100		234	Dam, 25; tunnel, 25.	2.1	1,100	5,500
Beaver Falls Creek, George Inlet, at Lower Lake outlet.	4.9	U. S. F. S.			75	792	10,000	62				

Swan Lake outlet, Carroll Inlet.			Aug. 24, 1916	440	435	[c]225	75,000	300[a]	150	1.25	3.5	12,000
Fish Creek near Sealevel mine.		U.S.F.S.R.	May 19, 1915	429	400	[c]275	66,000	1,700	35	1.5	290	10,500
Annette Island:												
Tamgas Lake	5.9	Chart	None		60	[a]150			50			1,000
Chester Lake	6.0	do	do		60	825	10,000	64	Dam, 50; tunnel, 100.		815	4,500
Deep Lake	10	do	do		100	[a]150						2,000
Millanson Lake	6.1	do										1,500
Admiralty Island:												
Hasselborg Lake outlet, entering Mitchell Bay, Kootznahoo Inlet.	[d]90		None		800	247		3,500[d]	60	6-7	247	18,000
Chichagof Island:												
Porcupine Creek near Nickel; west coast.												5,000
Falls Creek near Nickel; west coast.												3,000
Baranof Island:												
Green Lake outlet at Silver Bay.			Aug. 22, 1915	30.6	270 (storage for 210 sec.-ft.).	[a]240	42,	175[a]	165	0.4	340	6,500
Barnanof Lake outlet, Warm Spring Bay.		U. S. F. S.	June 28, 1915	411	365	134	90,000	700	100	.3	200	6,500
Second Lake on large stream at head of Cascade Bay.			Measurement, Aug. 14, 1917		420	[a]185	100,000		Dam, 50; tunnel, 50.		190	7,000
Patterson Bay near south entrance.			Measurement, Aug. 15, 1917.		60	[a]350	18,000	600[a]	Dam, 25; tunnel, 15.	.2	360	2,000
Small stream 500 feet south of entrance to Patterson Bay.			do		35							1,000
Stream at head of west arm of Patterson Bay.			Measurement, Aug. 16, 1917.			[a]120			40	.06	145	850
Big Port Walter	3.7	U. S. F. S.	Measurement, Aug. 17, 1917.	30	480	9,000	9,000	365	Dam, 10; tunnel, 25.	.08	460	1,200
Kosciusko Island: Stream entering Davison Inlet.	3.6	Chart		30	520[a]	6,000	6,000		do	1	510	1,400
Prince of Wales Island:												
Karta River, Karta Bay	49.5	U.S.F.S.R.	July, 1915	493	465	104	90,000	1,600[a]	50	.8	137	5,800
Myrtle Creek at Niblack Lake outlet.			July 30, 1917	92	53	450	10,000	383	Tunnel, 40		427	2,000
Myrtle Creek at Myrtle Lake outlet.					80	95	15,000	122	Dam, 20; tunnel, 10.		105	750
Reynolds Creek at Coppermount.	5.05	U. S. G. S.	Measurement, Sept. 14, 1915.		64	876	12,000	185	Dam, 15; tunnel, 60.	1	856	5,000
Mill Creek near Wrangell	50	Chart	June 17, 1915, to Sept. 30, 1917.	412	440	[c]100	112,000	500	125	1	166	6,500
Douglas Island:												
Treadwell mine ditch												[e]4,000

[a] Estimated. [b] Elevation of powerhouse, 80 feet. [c] Elevation determined by aneroid barometer. [d] Reported by Treadwell Mining Co. [e] Developed.

MINING IN CHITINA VALLEY.

By Fred H. Moffit.

INTRODUCTION.

All the mining districts in Chitina River valley were visited by the writer in 1916 and were described in an account published as part of the report on the progress of investigations in Alaska for that year.[1] Since then no description of individual mining properties in the region has appeared in publications of the United States Geological Survey, although G. C. Martin visited some of the properties in 1918 during a rapid journey through parts of Alaska and incorporated the results of his observations in the report on the investigation of Alaskan mineral resources for 1918. Material for the present account was collected by the writer during the early part of September, 1919, and the paper is presented as a report on progress in mining development rather than as a detailed description of ore deposits.

Mining in this region, as in all other parts of Alaska, was greatly affected by conditions that arose from the war. Prospecting practically ceased during war time, and even the assessment work on many claims was omitted under exemption allowed by laws passed for the relief of owners during the war. The scarcity of labor and the high cost of mining equipment and supplies made it unprofitable or at times impossible to carry on development work at some properties, which were allowed to lie idle.

The principal mining activity in the region in 1919 was on Kuskulana River, at Kennicott, and on Dan and Chititu creeks, in the Nizina district. No assessment work had been done on Elliott Creek and on Kotsina River up to the later part of September, but preparations were being made to do such work before January, 1920, for the new regulation regarding assessment work for 1919, as it was passed late in the summer, exempted no more than five claims in one holding and thus made it necessary for some claim owners to do assessment work who had not planned to do it in 1919.

[1] Moffit, F. H., Mining in the lower Copper River basin: U. S. Geol. Survey Bull. 662, pp. 155–182, 1918.

KUSKULANA RIVER.

Development work in the Kuskulana River valley in 1919 was done principally on three properties—the Alaska Copper Co.'s property on Nugget Creek, the North Midas Copper Co.'s property on Berg Creek, and the Chitina-Kuskulana Copper Co.'s property on Bigfoot Creek. The North Midas Co., which produced a small quantity of silver and gold, was the only company to do more than exploratory work. Some prospecting was done on Slatka Creek, where a little placer gold is contained in the gravels and where the presence of float gold has been known for some time.

The Alaska Copper Co., which owns the claims staked on Nugget Creek by James McCarthy in the early days of exploration in this district, after making a careful mine test of the copper-bearing vein which originally cropped out on the Valdez claim, decided to stop all development work and removed the machinery and equipment from the ground to Strelna. The developments on this property include about 4,000 feet of drifts, crosscuts, and shafts. The work disclosed a well-defined copper-bearing fault zone, which contained principally bornite and chalcopyrite. The vein near the surface consisted largely of high-grade ore, all of which was removed and shipped to the smelter, but it did not maintain its high copper content in the lower levels, and for that reason the ground was abandoned. Gold and silver are constituents of the ore, and a little native copper accompanied the copper sulphides in parts of the vein. The greatest depth below the outcrop of the Valdez claim attained by the workings is 420 feet, and the writer was informed by the manager that the relative quantity of chalcopyrite as compared with bornite in the lower levels was less than in the upper levels. Since 1916 about 160 tons of concentrates and hand-sorted ore have been shipped to the smelter. Previous shipments consisted of about two carloads of hand-sorted ore.

The mine was equipped with a mill, a small hoist, power drills, a drill sharpener, and other machinery. Power for the drills and hoist was furnished by two semi-Diesel engines. The mill contained a coarse crusher, one fine crusher, two jigs, and two tables. All this equipment, together with all other movable property, was hauled to Strelna on automobile trucks during the later part of the summer. A good road suitable for automobile travel was constructed at considerable expense between the mine and Strelna, on the Copper River & Northwestern Railroad, in 1917 and 1918, and has been in use for the last two seasons. This road for part of its length is on the line of the horse trail from Strelna into Kuskulana Valley, and is available for use by all the people in the valley. It is now in poor

condition because of heavy traffic in wet weather and should be repaired if it is to be preserved for automobile travel.

The North Midas Copper Co.'s property includes 18 lode claims, 4 placer claims, and a mill site on the east side of Kuskulana River 12 miles from Strelna. The first claims staked in this vicinity were located as copper claims and for several years were prospected in the hope of developing a copper mine. The ore body now being exploited, however, contains silver and gold as well as copper and is mined for those metals rather than for copper. The mine is on the south side of Berg Creek about 1¼ miles from Kuskulana River, at an elevation of 850 feet above the river bars. The ore body consists of quartz and a minor quantity of calcite containing arsenopyrite, pyrite, and chalcopyrite. It was deposited along a fault plane, cutting rocks which are prevailingly light-gray diorite, locally porphyritic, and dark-green fine-grained diorite. These rocks are in one of the major zones of faulting of the region and are cut by many other faults besides that containing the ore body. In places the tunnels also show white silicified limestone. The strike of the ore body is N. 70° E., and the dip is about 45° SE. but shows some variation. The thickness of the vein ranges from less than a foot to 7 feet.

Mining has been conducted on two levels 100 feet apart and reached by different adits. A short intermediate level has also been driven from the upper level. The main upper and lower levels have been connected, however, and the ore from the upper level is drawn off through the lower level. More than 1,600 feet of levels and adits have been driven.

The gold and silver content is variable in different parts of the ore body and ranges from a few dollars to several hundred dollars to the ton. The silver is present in greater quantity than the gold and in some places has a ratio to gold as great as 4 to 1. The most valuable ore is the oxidized part of the vein near the surface.

A cable tram equipped with buckets having a capacity of 3½ cubic feet conveys the ore from the mine to the mill, which is built on a terrace near Kuskulana River. This mill has a capacity of 20 tons in 24 hours and is driven by water power furnished by Berg Creek. A wood pipe line 2,200 feet long carries water from the intake to the mill, where it supplies both power and water for milling. The tramway was constructed in the spring of 1919 and was not completed till the greatest flow of water in Berg Creek was over, and consequently the mill was operated for only a few days at the end of the season.

Communication with Strelna has been greatly simplified by the construction of the road from Strelna to Nugget Creek and of the Government bridge over Kuskulana River 1¾ miles below the mouth

of Trail Creek. The mill is only 1½ miles from the bridge and has been connected with the Nugget Creek road by a branch road 2¼ miles long, which leaves the main road near the crossing of Squaw Creek. This road is available for automobile travel and has been used for two summers, but like the main road will require further expenditure of work and money before it is in first-class condition.

The Chitina-Kuskulana Copper Co. owns 21 claims, 5 of which are mill sites, on Bigfoot Creek, between Berg and Trail creeks, on the southeast side of Kuskulana River, about 13 miles from Strelna. Bigfoot Creek is nearly 4 miles long, and most of its course is through an area of light-colored porphyritic diorite. Its upper part cuts Triassic shales and limestone and Jurassic limestone, sandstone, and shale. The mountain northeast of the creek is all diorite except near the head of the stream, where Jurassic sediments overlie the igneous rocks. Most of the claims are on the southeast side of the creek, where the rocks below the Jurassic sediments are heavily mineralized in many places, principally with magnetite.

Most of the development work has been done on two claims known as the War Eagle and Calcite claims. The War Eagle claim and tunnel are on the mountain slope southwest of the creek, 200 feet above the "middle camp," or 1,300 feet above the "lower camp," which is on the bars of Kuskulana River. The tunnel is 200 or 300 feet above timber line, about 3,400 feet above sea level. It is 100 feet under cover and cuts a silicified limestone containing dark bands, possibly intrusive dikes, mineralized with pyrite and chalcopyrite and showing green copper stains. Between the tunnel and the base of the Jurassic sandstone beds, about 200 feet higher on the mountain slope, are large exposures of magnetite, which is older than the sandstone, for the conglomeratic beds near the base contain rounded pebbles of the magnetite.

The Calcite claim and tunnel are high on a sharp, narrow ridge separating Bigfoot Creek from a southern branch of Trail Creek. The tunnel, 600 feet long, is at an elevation of about 4,800 feet above sea level and lies in or near the contact of a diorite mass on the north and silicified limestone on the south. These rocks have been greatly disturbed through faulting, by which the underlying Triassic limestone and shale have been thrust in a northerly direction over the younger Jurassic sediments. The fault doubtless played a large part in the deposition of the metallic minerals of this creek and of Berg Creek. It strikes north-northwest and dips 25° N. to 30° S. It extends at least as far as from Chokosna River to the west side of Kuskulana River, and probably farther. Both the white altered limestone, of undetermined age, in the tunnel and the rocks adjoining the tunnel are much fractured and sheared along the fracture planes,

where there is rusty iron-stained gouge and more or less laminated rock containing pyrite and copper-bearing pyrite or chalcopyrite. Copper staining is abundant.

The property of the Chitina-Kuskulana Copper Co. is equipped with a power plant situated on the low, timber-covered gravel bars within a short distance of Kuskulana River. This plant includes an 80-horsepower engine, a 125-horsepower wood-burning boiler, a 62½-kilowatt 3-phase alternating-current generator, and a 7½-kilowatt exciter. Current is carried to the War Eagle claim, where the company has installed a 50-horsepower 3-phase motor, an air compressor, air receivers, two piston drills, jack hammers, and other necessary equipment, including a drill sharpener. Power drills have not yet been used in the Calcite tunnel, but a 6-horsepower gasoline engine, a blower, and 600 feet of air tubing are used to provide ventilation at the tunnel face.

The bars of Kuskulana River furnish easy communication with the bridge over the river and thus with the road to Strelna, making it much easier than formerly to get supplies in summer. The Government bridge recently constructed by the Alaska Road Commission is undoubtedly of great benefit to all the property owners on the east side of Kuskulana River, for its obviates the difficulty and danger of fording that stream, which at times is practically impassable.

A separate company, named the Mount Wrangell Copper Co. but under the same management as the Chitina-Kuskulana Copper Co., controls the Copper Queen, formerly the Rarus group of claims, adjoining the War Eagle group, and also two groups of claims called the Broken Leg and the Mineral King groups on Chokosna River. It is expected that work will be done on the Broken Leg group in 1920.

Benito Creek is a small stream flowing into Kotsina River from the mountains south of Elliott Creek. It is about 9 miles north-northwest of Strelna but is reached from that place by trails considerably longer. Interest in Benito Creek lies in a gold-bearing quartz vein commonly known in the district as the Canning property, from the name of one of the owners who discovered the vein in 1913. The property consists of five recorded claims situated a short distance below timber line on Benito Creek and is owned by Jack Canning and Benito Contino.

The vein consists of quartz and calcite, with quartz predominating, and ranges from 2 to 3 feet in thickness but averages about 30 inches. It dips steeply to the east and strikes N. 70°-75°W., cutting a succession of dark-colored igneous rocks that include both dense basaltic members and coarser granular phases, with abundant horn-

blende. These rocks grade into each other without sharp l
aries. They are considerably altered and are sheared, parti
near the vein.

The vein originally appeared in the creek as a mass o
white quartz but has now been proved by a succession of five s
holes to extend for at least 500 feet. The deepest of these
penetrated the vein 15 feet. Much difficulty was experience
water, which flowed along the rock surface beneath the gravel
ing, and to obviate this trouble an automatic dam was cons
on the creek and two channels ranging in depth from 2 to
were sluiced across the claims. Owing to irregularities in th
rock surface these cuts do not expose the bedrock in many pla

The vein is mineralized with iron and copper sulphides,
pally arsenopyrite, which near the surface are much oxidiz
have colored the shattered quartz with rusty iron stains. In
the oxidized vein has furnished some handsome specimens
gold. Small particles of free gold are rather common in much
oxidized vein and contain or are accompanied by silver, as is
by the assays.

On the left-hand side of the creek about 100 feet downstrea
the vein is another quartz vein carrying arsenopyrite and a
metallic mineral, probably hematite. This vein strikes N. 10

About one claim length still farther downstream is a vein o
shattered quartz 8 to 9 feet wide, containing pyrite and arseno
Several open cuts have been made on this vein, but no parti
encouraging results have been gained.

Benito Creek at present has no adequate means of commun
with Strelna. It lies on the direct route to Elliott Creek an
be reached by any one of several trails that have been made si
railroad was constructed. The chief difficulty with all these
which are pack trails only, is that parts of them are wet ar
except in the driest weather or in winter, when they are not us

KENNICOTT.

The property of the Kennecott Corporation near Kennico
includes three working mines, for in addition to the Bonan
Jumbo mines the corporation has acquired the Mother Lode
formerly operated from the McCarthy Creek side of the rid
tween Kennicott Glacier and McCarthy Creek. Formal contro
Mother Lode began on May 1, 1919, and since that time ore fr
Mother Lode has been delivered to the mill at Kennicott ov
Bonanza tramway. The three mines are now connected
ground, so that it is possible to pass from one mine to any o
great advantage in operation and management. The conn

are made from the 600-foot level of the Bonanza to the 500-foot (?) level of the Jumbo and from the 800-foot level of the Bonanza to the Rhodes (700-foot?) level of the Mother Lode mine. On the connecting levels the slopes of the Bonanza and Jumbo mines are 4,370 feet apart. The shaft of the Mother Lode is 1,400 feet from the incline of the Bonanza.

Much work has been done in the three mines to facilitate mining and handling the ore. New slopes were driven in both the Bonanza and Jumbo mines, and new dumping pockets were provided underground. New hoisting machinery was also installed. In addition the loading station of the Jumbo tram is being moved underground. The new station will no longer be in danger from movements of the Jumbo Glacier and will add greatly to the comfort of the men who load the tram cars, for they will be well underground and no longer exposed to the winter storms. Development work has now been carried below the 1,000-foot level of both mines, although the new inclines had not fully reached that depth at the time of visit. There is stoping ore on all the levels of the Jumbo mine. Most of the ore of the Bonanza mine above the 300-foot level, however, has been mined out except in the pillars, which contain much ore and have not been touched. Exploratory work, both by drifts and crosscuts and by diamond drilling, has been pushed in all parts of the property. The Bonanza and Jumbo mines employ about 150 men each.

Work in the Mother Lode mine in 1919 was directed mostly toward exploration of the mine and toward removal of the ore already mined and piled on the dumps by the previous owners, for because of the cost of transportation by truck from the mine to McCarthy only the highest-grade ore was shipped and the ore of lower grade was left. Much of this lower-grade ore was scraped up in the summer of 1919 and hauled by electric engines from the Mother Lode dumps to the Bonanza incline on the 800-foot level and thence sent to the mill at Kennicott. Within the mine a prospecting shaft was sunk from the Pittsburg (600-foot) level to a point below the 1,100-foot level, and crosscuts were driven to the ore-bearing zone. Prospecting by drifts and with the diamond drill was carried on from the crosscuts at the same time.

An increase in the capacity of the Bonanza tram to about 1,000 tons a day makes possible the handling of ore from both the Bonanza and Mother Lode mines.

Part of the ore delivered to the mill over the Bonanza and Jumbo trams is sorted out and shipped as high-grade ore, but the greater part passes through the mill for concentration. The mill tailings all pass through the leaching plant, where they are deprived of the light-weight copper-carbonate minerals left in them on leaving the mill. The leaching plant treats 600 tons of ore a day.

DAN AND CHITITU CREEKS.

The gold placers of Dan and Chititu creeks were not visited by the writer in 1919, and the few statements made here are based on statements of the owners of the properties or on information from other sources. An estimate of the gold production of the two creeks is contained in the first part of this volume.

Little in the way of new installation or new discovery has taken place on Dan Creek, but the mining plants already installed have continued operation as in previous years. The largest operator is the Dan Creek Mining Co., whose plant was installed several years ago and has been in operation each year since. In addition work has been done on a smaller scale by other owners on the bench claims of Dan Creek and on claims on Copper Creek, the southern branch of Dan Creek.

The principal fact of note relating to Chititu Creek is the consolidation of the claims on lower Rex Creek and part of those on White Creek, the two branches of Chititu Creek, with the claims on Chititu Creek itself. This was brought about by the purchase of certain claims on Chititu Creek just below the junction of Rex and White creeks. Mining on these claims and on some of the claims on Chititu Creek has been hampered by a conflict of water rights. This difficulty is now obviated by the consolidation, and a proper exploitation of the gravels involved is possible. This property now includes not only the creek claims already mentioned but also certain bench claims on the east side of Rex Creek a short distance above Chititu Creek, which heretofore have been worked independently of the claims on Chititu Creek. The two hydraulic plants on the Rex and Chititu creek claims were in operation as formerly.

The work just mentioned as having been in progress on Rex and Chititu creeks was the principal mining done on those streams in 1919, but some further mining was done by other operators on upper Rex and White creeks which contributed a small amount to the gold production of the Nizina district.

MINING DEVELOPMENTS IN THE MATANUSKA COAL FIELDS.

By Theodore Chapin.

INTRODUCTION.

The only coal-mining activity in the Matanuska Valley in 1919 was the working of the Government-operated mines at Eska and Chickaloon by the Alaska Engineering Commission in charge of Sumner S. Smith, resident engineer. This paper is intended as a brief statement of the operations of the year, to supplement a more extended report on the geology and developments recently published.[1]

ESKA MINE.

The principal operations were at Eska, where an average of 85 men were employed throughout the year and approximately 40,377 tons of coal was mined. This coal was taken from all six of the productive beds, the Martin, Shaw, Eska, Maitland, David, and Emery, but the greater part came from the first four named.

The coal deposits at Eska lie in an open syncline that trends approximately east, about perpendicular to the creek, which has cut across the beds and has exposed a natural section. The mining by the Alaska Engineering Commission has been done only on the north limb of the syncline, above water level. During 1919 the Emery east and David east gangways were extended 353 and 448 feet, respectively, this work being largely in the nature of development. On the west side of Eska Creek the Eska, Shaw, and Martin tunnels were extended 275, 407, and 86 feet, respectively. The Shaw is now used as the main haulageway, and the 20-pound rails formerly used have been replaced by 60-pound rails and the track gage widened from 24 to 36 inches.

About 1,660 feet from the portal of the tunnel the Martin, Shaw, and Eska beds are cut off by a fault, whose position was known approximately from the surface outcrops. During the open season of 1919 a careful study was made of the structure of the beds as shown on the surface above and just beyond the present face of the Shaw west tunnel. The beds were opened by pits and at critical localities

[1] Chapin, Theodore, Mining developments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 131–167, 1920.

by stripping, which showed the conditions illustrated in figure 2. The Eska, Shaw, Martin, and Emery beds were identified, and one or another was traced for nearly 1,000 feet. Between the position of these beds and the position of the present workings, however, there is a downthrown fault block from 100 to 300 feet wide in which the coal beds are either absent or badly broken. The beds west of this fault block appear to be but little disturbed with reference to the position of the beds in the present workings. From the strike and dip of the outcrops the approximate position of these beds on the level of the

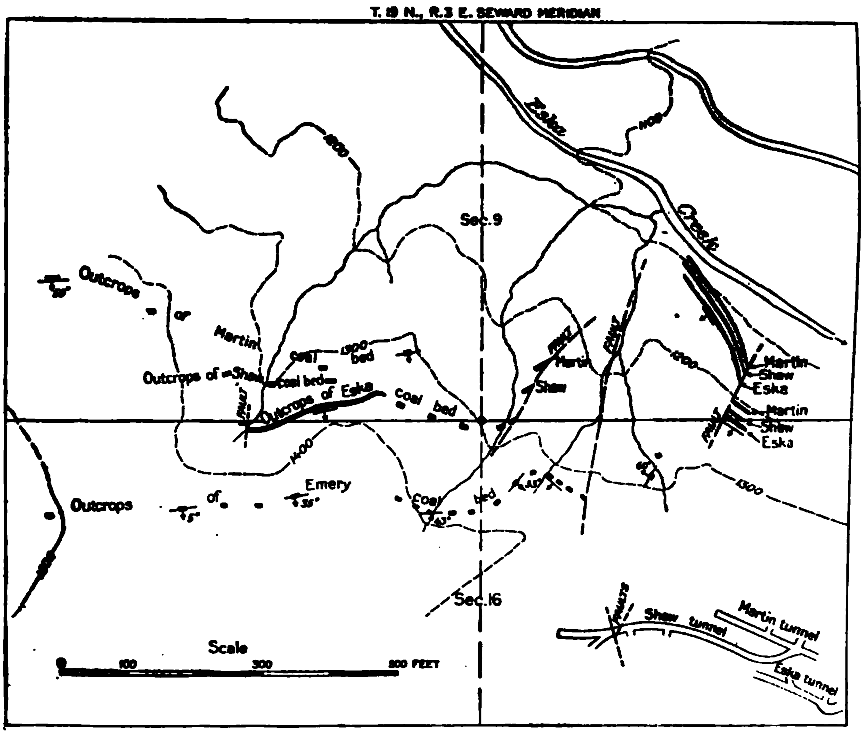


FIGURE 2.—Sketch map of part of Eska mine, Matanuska Valley, showing position of face of Shaw, Eska, and Martin workings, outcrops of coal beds, and structural relations.

present workings has been calculated, and work is now in progress to drive the Shaw west tunnel through the fault block to connect with the beds west of the faulted ground.

Where the Shaw tunnel enters the fault block it cuts a massive sandstone which occurs just above the Eska coal bed and which has been carried downward by the movement along the fault. Excavation through this hard rock will necessarily be slow.

On the south edge of the syncline open cuts and churn-drill holes show the presence of all six beds and indicate a considerable area of

minable coal from which a large tonnage can be mined with probably no greater difficulties than were encountered in the present workings. So far all the mining has been done from water-level tunnels, from which rooms are opened.

The cleaning plant has been in operation throughout the year, and plans are under way for the erection of a washery.

CHICKALOON MINE.

At Chickaloon an average of 35 men were employed in 1919 and approximately 4,176 tons of coal was mined incidentally to development operations. On account of the difficulty of using the old slope as a working shaft a new slope was extended along bed 8 at an angle of 32° to 46° for 238 feet, to the second level, at an elevation 312 feet below that of the portal, and a station was cut, from which drifts were extended east and west 206 and 434 feet respectively.

The new slope from the first to the second level passed from bed 8 through a faulted zone containing considerable crushed coal into bed 5, which is exposed in the station. In extending the slope it was not evident to the operators whether a fault or a squeeze in the bed was being encountered, but when the second level was reached bed 5 was identified. It is thus evident that the fault is not marked by a definite plane but by a crushed zone containing drag blocks of coal, and its direction is known only by the relative position of beds 5 and 8.

On the west drift from the station the workings pass from bed 5 to bed 5½ along the crushed zone of a low-angle fault of slight displacement similar to the one in the slope that has cut off bed 8.

LODE DEVELOPMENTS IN THE WILLOW CREEK DISTRICT.

By THEODORE CHAPIN.

MINING IN 1919.

Mining operations in the Willow Creek district in 1919 were carried on at five mines, the same number as in 1918. The Gold Cord mine, which was operated in 1918, was idle, but the War Baby made its first production in 1919 and was operated throughout the open season. Considerable prospecting was done, and some bona fide sales were made. The value of the gold and silver produced in 1919 was $159,458.

The Willow Creek district is being developed mainly for its gold-bearing lodes, which occur as well-defined fissure veins in quartz diorite. Two copper-bearing lodes, however, one on the eastern and one on the northern edge of the district, have been located recently, and enough annual assessment work has been done to hold the claims.

The presence of telluride ores in the gold-quartz veins has been reported from time to time. Since 1913 the Survey has tested these so-called tellurides with negative results. In 1919 it was again reported locally that telluride ores occur at a number of properties in the Willow Creek district. Tests for tellurium on samples submitted were made in the Geological Survey office at Anchorage, with negative results, and these tests were corroborated by assays made on the same ore by the Survey chemists in Washington. It is not intended to say that tellurides do not occur in the Willow Creek district, nor that they will not be found. It is not likely, however, that rich deposits of telluride ores occur here, for the geologic association of the Willow Creek lodes does not favor their occurrence. The known rich deposits of telluride ores of gold and silver occur mostly in comparatively shallow veins in Tertiary lavas. The Willow Creek lodes are not associated with effusive volcanic rocks and are believed to be of much greater depth and persistence than the type of veins in which rich deposits of tellurides are usually found.

The mines and prospects on which development work is being continued are shown on the accompanying map (Pl. VI). The following descriptions of operations deal only with recent developments.

MINES AND PROSPECTS.

WILLOW CREEK AND TRIBUTARIES.

The Gold Bullion mine on Craigie Creek, operated by the Willow Creek Mines, continued to be the most constant producer in the district. The mine and mill were operated throughout the open season, from May 26 to October 16, employing from 60 to 70 men. The ore was supplied principally from tunnels Nos. 3, 4, and 5. Plans were recently made to erect a plant for the treatment of the slimes, which have been ponded since milling operations were begun. Some development work was done on the Lucky Shot and Panhandle groups of claims, on which options were taken last fall by the Willow Creek Mines. The Lucky Shot vein was traced across five claims by open pits and a short tunnel that was started to open the vein. It strikes N. 60° E. and dips 45° NW. The Panhandle group consists of four claims, which cover a vein of quartz from 6 to 8 feet across, with horses of country rock. This vein strikes N. 85° W. and dips 38° N. But little work has been done on it.

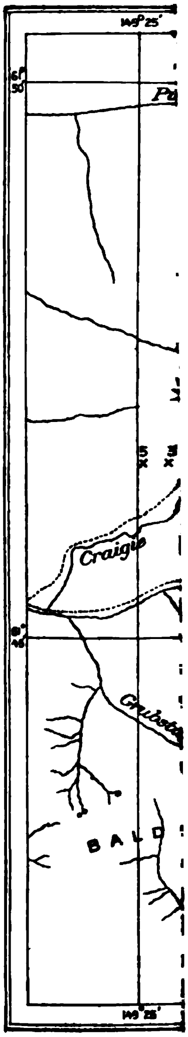
The owners of the War Baby mine, on lower Craigie Creek, which made its first production in 1919, completed the erection of a Straub mill and operated the mine throughout the season. The workings consist of two short openings on the vein and a third that is being driven to tap the vein at a lower level. Underground development work was carried on during the winter.

Some development work was done on the Golden Light claims, on the southeast side of Craigie Creek, and a mill was erected, but no production was made.

The Leona and Gold King claims, near the head of Craigie Creek, are being developed by the Brassel Bros. A large fissure vein, which is said to have been traced for six claim lengths, is 19 feet across. The walls are well defined, with 6 inches of gouge on the footwall and 18 inches on the hanging wall. The vein is composed of altered quartz diorite with stringers of quartz. It strikes N. 70° E. and dips 42° NE. About 100 feet below it is a parallel quartz-feldspar dike with some vein quartz which carries a little gold. On the Gold King No. 3 and Leona claims a number of surface workings show several small veins of rich quartz, and a tunnel is now being driven to open these veins.

Development work was also continued on the Newman and Miller claims, on upper Craigie Creek.

A copper prospect near the head of Purches Creek is covered by the Dixie group of claims. The ore deposit consists of a pegmatitic vein 8½ feet wide which strikes N. 55° E. and dips 55° SE. At each border of the vein is a coarse pegmatite composed of quartz and orthoclase



1. Gold Bullion mine
2. Golden Light pros
3. War Baby mine.
4. Panhandle prospe
5. Lucky Shot prosp
6. Gold King prospe
7. Newman & Miller
8. Dixie prospect.
9. Little Willie prosp
10. Brooklyn-Willow C

with large foils of muscovite and particles of chalcopyrite. The central part of the vein is milky-white quartz cut by irregular stringers of chalcopyrite with a little bornite. The deposit is opened at one place by an open cut across the vein which shows the following section:

Section in open cut on Dixie claims.

	Ft.	in.
Pegmatite	1	0
White glassy quartz with stringers of chalcopyrite and bornite	5	0
Lens of chalcopyrite		5
Pegmatite	2	0

The sulphides are essentially pure chalcopyrite and bornite, which occur as irregular masses in the quartz.

The Little Willie claims were recently staked by Long & Holland on the divide between the heads of Craigie, Purches, and Fairangel creeks. The principal vein crops out on Craigie Creek above Craigie Glacier and has been traced across the ridge into the head of Fairangel Creek. This vein strikes N. 77° W. and dips 26° NE. It is composed of quartz stringers from an inch to 6 inches wide which closely follow a green igneous dike made up entirely of secondary minerals, essentially sericite, quartz, and calcite. Originally this altered rock was probably granite or monzonite, composed of quartz and feldspar with some hornblende or mica. The quartz vein is evidently of later date than the dike but follows it closely along one wall or the other and in places occurs as several parallel veins within the igneous rock. The vein is small but is very persistent and from the amount of free gold in the outcrop is apparently very rich.

A copper-bearing vein from 1 inch to 18 inches thick occurs on Fairangel Creek on the ridge above the glacier. This vein is composed of quartz and carries gold, specks of chalcopyrite, and tiny veinlets of molybdenite.

The claims of the Blue Quartz Mining Co. are near the head of the north fork of Peterson Creek, a northern tributary of Willow Creek. Three parallel granitic dikes, composed of quartz and orthoclase, with clusters of tourmaline, strike N. 63° E. and cut the quartz diorite country rock. One of these dikes, 8 feet wide, gradually passes along its strike into a quartz vein that carries some gold and visible particles of chalcopyrite and tetrahedrite. Intersecting this main quartz vein are several short gash veins of quartz with considerable pyrite. These veins pinch out a short distance from the main fissure. Open cuts have been made on both the gash veins and the main vein, and a tunnel has been started to cut the main vein. The persistence of this fissure vein is not known. In one direction it apparently merges into a granite dike, and in the other it is covered with débris and has not been traced.

On Willow Creek some development work was carried on by Milo Kelly on the claims of the Brooklyn-Willow Creek Gold Mining Co.

FISHHOOK CREEK.

The Alaska Free Gold mine, mill, and cyanide plant were operated throughout the season, working from 20 to 30 men. Mining operations were continued in the old workings, and a little work was done on the Eldorado claim.

The Gold Cord mine, on upper Fishhook Creek, which yielded a production in 1917 and 1918, was not in operation.

ARCHANGEL CREEK.

Control of the Talkeetna mine, near the head of Fairangel Creek, was acquired in the fall of 1918 by W. F. Rock, who operated it throughout the open season of 1919 and continued development work. Mining operations are now confined to one tunnel extended about 300 feet along the vein, which strikes N. 45°–60° E. and dips 40°–60° NW. For the first 200 feet from the portal of the tunnel the vein is from 5 to 18 inches wide, but it widens abruptly and for the next 100 feet to the face of the tunnel is from 5 to 8 feet wide and in places contains 5 feet of solid quartz. Above this tunnel are other veins which are not being developed at present. The ore is banded rusty white and gray quartz, with considerable gouge. The quartz contains some visible gold, and in spots the ore is very rich, but the workable rock is confined to definite pay shoots within the vein.

The Little Gem Gold Mining Co. bonded the Webfoot claims and other property on Archangel Creek and continued development work during the winter of 1919–20.

The recently formed Giant Gold Mining Co. is developing the Marmot group of claims, on Archangel Creek. Supplies and equipment were sledded in to the property in the fall, and work was continued during the winter.

Tunnel driving was continued by Fern & Goodell during the spring of 1919 on their property on Archangel Creek.

The Mabel mine was operated for 160 days, from May 25 to November 1, by a small crew of men, and tests and mill runs were made on the ore. The work of the year was mostly intended to develop the mine. A crosscut tunnel was driven for 150 feet, and drifts were extended for 340 feet. The opening of two new ore bodies is reported. The Loveland-Alaska Mining Co., of Loveland, Colo., has taken a lease and bond on the mine and will continue active development under the management of H. J. Phillips.

REED CREEK.

Development work was continued on the property of the Le Roi Mining Co., on Good Hope Creek, a tributary of Reed Creek. The claims are on the high divide between Reed and Good Hope creeks about 1½ miles east of the Loveland-Alaska mine and may be reached from the Reed Creek road. Since this property was located in 1917 development work has been carried on preparatory to active mining.

The Skarstad claims, known as the Opal group, were staked in 1919 on the west side of Reed Creek about a mile from its mouth. Two parallel veins have been traced by surface pits for two claim lengths. The veins strike N. 50°E. and dip 50°NW. The outcrop of the upper vein is from 3 to 4 feet wide and consists of quartz and gouge along each wall inclosing considerable altered diorite, all of which carries gold. The hanging wall is mineralized diorite with stringers of quartz and also contains gold. The lower vein is from 3 to 5 feet wide. It is made up of stringers of quartz and gouge in altered diorite and carries much pyrite from which gold may be panned after roasting. A tunnel was started in the fall, and work was continued during a part of the winter.

The Idamar claims, adjoining the Skarstad property on the northeast, were staked by J. B. Larsen in 1919, and a little surface stripping was done.

J. F. Burr is developing the Mary Ann group of claims, on the east side of Reed Creek, half a mile above the mouth of Good Hope Creek. A tunnel is being driven to intersect a vein that has been traced along the surface. It strikes northwest and dips northeast.

The Snow King claim, on the ridge west of Reed Creek, is being developed by J. F. Austin, to open a vein of quartz that is said to have been stripped for 4,000 feet.

LITTLE SUSITNA RIVER.

The Gold Mint group of seven claims was recently located by J. B. Hatcher on Little Susitna River about 2 miles above the mouth of Archangel Creek. The country rock is gneissoid quartz diorite. Several veins intersect the property. The upper vein strikes N. 50° W. and dips 42° SW. It is composed of 10 to 17 inches of bluish-white quartz, with considerable pyrite and chalcopyrite and some visible gold. The vein has been traced for some distance on the surface and appears to be persistent. The lower vein strikes N. 30° W. and dips 62° SW. Where exposed by several surface cuts the vein consists of milky-white quartz with rusty streaks and blotches from the oxidization of pyrite. Between these two veins are two or three others that strike about north. These are apparently barren where

exposed. The developments consist of a short tunnel that is being driven on the upper vein and surface pits to prospect the veins.

The Maverick claims were located by J. B. Wilson on Lone Tree Creek on a quartz vein reported to be 2 feet thick and similar in appearance to the upper Gold Mint vein.

The Moose Creek copper claims, on the ridge between tributaries of Little Susitna River and Moose Creek, have not been visited by members of the Survey, and the following information is abstracted from a report by Mr. F. L. Thurmond, of Anchorage. The claims are on the eastern border of the Willow Creek district, on the divide between Little Susitna River and Moose Creek, at elevations ranging from 2,300 to 4,800 feet. The property is reached from Moose Creek. A wagon road follows the creek for 5 miles to the Baxter mine, from which a trail extends to the property on Iron Creek, a distance of about 12 miles. The property consists of two groups of claims, one of four claims and an adjoining group of seven claims. These claims were located in 1914 and 1915 by J. H. McCallie and associates, of Anchorage. The ore deposit is from 30 to 100 feet in width, strikes about N. 75° E., and dips about 80° SE. It does not appear to have a well-defined wall, however, and merges gradually into the quartz diorite country rock. At one place an open cut has been made 25 feet diagonally across the deposit, which at this locality consists of pyrite, pyrrhotite, chalcopyrite, and sphalerite carrying gold and silver. It is said to have been traced for 7,000 feet along the surface but has not been explored in depth. The copper, gold, and silver contents are said to be low, but the apparent size of the ore body and its proximity to the railroad and to the coal deposits recommend it for careful examination.

MINERAL RESOURCES OF THE GOODNEWS BAY REGION.

By George L. Harrington.

INTRODUCTION.

The Goodnews Bay region as here considered embraces the territory lying south of Arolic River and draining into Kuskokwim Bay. It thus includes the Arolic and Goodnews river basins and the intermediate area. Some information regarding the area south of Goodnews Bay as far as Cape Newenham is also included in this paper. The surveys of this region in 1919 covered an area of approximately 1,400 square miles and extended from longitude 159° 40′ to 162° west, and from latitude 59° to 59° 40′ north. A traverse of the Yukon-Kuskokwim portage was also made. R. H. Sargent, topographic engineer, in general charge of the work, made the topographic surveys on which the geologic work north of Goodnews Bay was based. South of Goodnews Bay charts and maps of the United States Coast and Geodetic Survey were used as a base. The geologic mapping and investigation of mineral resources were done by the writer. A cook and a station assistant to Mr. Sargent completed the party.

The party left Seattle on the power schooner *Ozmo* on June 19 and made a landing in Security Cove, just east of Cape Newenham, on the evening of July 4. About two-thirds of the supplies and provisions and all other equipment were landed in the boats of the Survey expedition at the same time. The supplies were transported throughout the season by boat or by back packing. A 30-foot poling boat and a 20-foot dory, together with a 2-horsepower gasoline engine of the detachable hang-over type, were obtained at Seattle, and the poling boat was used on Goodnews River, and the dory for such shore work as was necessary. Field work ended at Kwinak (Quinhagak post office) on August 18. The return to Seattle was made by way of Bethel and the Kuskokwim-Yukon portage, Mr. Sargent with the field assistants going up the Yukon and the writer going down and continuing to St. Michael and Nome, where he spent a few days in the collection of statistics while awaiting the steamer *Victoria*. Transportation from St. Michael to Nome was afforded by the United

States Coast Guard cutter *Bear*. Seattle was reached October 19, after a 12-day trip from Nome that included stops at St. Michael, Dutch Harbor, Akutan, and Isanotski Strait.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

Approach to this region is difficult in times of storm or fog on account of the shallowness of Kuskokwim Bay, and for this reason larger vessels must move with the tides or follow carefully the surveyed channels. A small cove just west of Security Cove affords a fair haven for small boats from easterly storms, and Security Cove is so shaped as to give protection from practically all directions. Shoals and bars off Chagvan and Goodnews bays make entrance into them difficult in rough weather, and, in addition, strong tidal currents and eddies occur at the mouth of Goodnews Bay. Traveling along the shore is done mostly in periods of calm weather or when there is an offshore breeze, the shallowness of the bay making travel in small boats particularly unpleasant in any other weather.

From Cape Newenham to the small cove west of Security Cove and from Security Cove north to Chagvan Bay there are many stretches where it is not possible to get along the beach except at very low tide, and a few where it is not possible to follow the beach even then. From Chagvan Bay to Goodnews Bay the beach is sandy, hard, and firm and may be followed on foot. The same is said to be true of the stretch from Goodnews Bay to Carter Bay, but from Carter Bay to the northern edge of Jacksmith Bay the beach is muddy and is cut by tidal sloughs, and at low tide the muddy tide flats extend out for several miles. From the north side of Jacksmith Bay to Kivinak there is another sandy beach with firm footing, although it appears likely that this beach, as well as a considerable area of the tundra back of it, is covered at extreme high tides or in times of heavy storms, as logs are often found a considerable distance back from the beach. Tidal flats occupy a considerable portion of Goodnews Bay, the sand and silt brought down by Tunulik and Goodnews rivers having partly filled its east end. Both these streams are tidal in their lower courses, and so to a lesser extent are the Arolic and Kanektok, and in ascending them advantage is usually taken of the flood tide, as there is an appreciable current on the ebb or slack tide. In their lower courses these rivers are, however, relatively sluggish and their channels are tortuous. (See Pl. VII.) Farther upstream the current quickens but is by no means uniform, as it alternately accelerates on the riffles and slackens in the stretches between. It was necessary to line the boat up some

of these riffles, and it was judged that the current was running at a rate of 7 or 8 miles an hour.

From Cape Newenham to Goodnews Bay, except for a stretch on each side of Chagvan Bay, the hills and low mountains rise almost directly from the water. North of Goodnews Bay, however, the hills recede eastward from the coast, and there are no more high hills or mountains along Kuskokwim Bay or River south of the portage to the Yukon. At Bethel the mountains lie several miles east of the river, though plainly visible on clear days. Jag Mountain, east of Cape Newenham, rising directly from the water's edge to a height of 2,291 feet, is the highest mountain along the coast, although there are a number of other mountains in the Goodnews River basin which are from 2,700 to a little over 3,000 feet in height. Most of the higher mountains are sharply jagged in outline, but those of intermediate elevation are less jagged, and the lower hills are usually well rounded, though showing a few small projecting rock points. In the southern part of the region there are numerous examples of terraced altiplanation forms on a relatively small scale, but elsewhere these terraces are rare, although not entirely absent. Their scarcity is probably due to the fact that other types of erosion have been more active and so prevented the development of these land forms.

The intermontane areas are low, flat, and broad, and numerous ponds and lakes occur in the poorly drained valleys, especially in that which connects the present valleys of the main branches of Goodnews River.

GLACIATION.

So far as was observed there are no glaciers in the Goodnews Bay region, but their former presence is made apparent by numerous topographic features such as are peculiar to glaciated regions. Near the coast there is relatively little evidence of their former presence, but this is accounted for on the hypothesis that such evidence may have been destroyed by postglacial marine inundation. In the mountains, away from the coast, many of the streams head in typical glacial cirques, in which are small lakes, and U-shaped valleys lead from these cirques to the larger tributary valleys of the main drainage systems. Erratic boulders on divides are fairly common, and faceted blocks at elevations well above the present stream channels were noted in a few places. Deposits that could be definitely classed as morainal were not seen, but it is believed that much of the material composing the unconsolidated deposits between Kuskokwim Bay and the front range of hills is of glacio-fluviatile origin. Perhaps the best example of morainal material seen was in the valley of Canyon Creek. A large stream enters Canyon Creek from the north through a deep channel cut in unconsolidated sand and gravel; a

short distance below their confluence the creek flows through a pass in the hills in a rock-cut canyon at least 75 feet deep for perhaps half a mile before crossing the wide valley of Goodnews River, into which it finally empties. The stream now flows on the south side of the pass, very close to the base of the hill on that side. Numerous small lakes, with gravel banks, lie in the pass. This lake-dotted deposit is interpreted as being a moraine that fills the preglacial valley of the creek. As the glacier retreated the stream sought the lowest place through the pass, which happened to be at one side of the deposit. Since reaching bedrock it has continued cutting until it has formed the present canyon. At the confluence of the two streams, where both are flowing through unconsolidated material, the channel is approximately in the position of the preglacial channel.

It is believed that numerous changes in drainage, even of the major streams, were brought about by the glaciation of this region. The low lake-dotted pass between the forks of Goodnews River was probably the preglacial channel of that stream. The pass has been filled with gravel, as is shown by the gravel banks of the many lakelets which lie in it. These lakes differ from the lakes of flood-plain origin and from some of the lakes lying at elevations above the flood plains, practically all of which are in mossy bogs and have banks of peat or moss.

NIVATION.

Nivation, or erosion somewhat similar to glaciation but on a much smaller scale and produced by accumulations of snow, which may last from one season to another, has been an effective agent in the formation of a number of minor topographic features in this region. To nivation is attributed the abundance of small valleys of general U-shaped cross section. Such valleys were especially noted on the tributaries of Bear and Canyon creeks and also in the group of hills on the south side of Goodnews River about 20 miles from its mouth. Forms that are probably due to nivation were also observed on the slopes of the hills in the vicinity of Security Cove.

At the heads of a few of the valleys the snow banks develop cirque-like forms, one of which was observed near the granite-limestone contact in the vicinity of the glacial lake at the head of Tunulik River.

TRAVEL AND TRANSPORTATION.

In many respects this region is one of the most inaccessible in Alaska for a small expedition. For a number of years it has been necessary to come overland from the Yukon either by the portage or by way of Iditarod, or to travel in a kayak or canoe, or by a small schooner or sailing boat from Togiak. During the summer of 1919 an 800-ton schooner was placed on the run between Seattle and Bethel, and this boat made two trips and afforded the most satisfactory

freight and passenger service that has been available to the inhabitants of the lower Kuskokwim for many years. During the winter of 1918–19 there was an acute shortage of provisions, which had to be brought at heavy expense from the Yukon, on account of the failure of one of the supply schooners to bring in winter provisions. This schooner was scheduled to bring in supplies during 1919 also but had not reached Bethel when the Geological Survey party left the region in September.

Practically all supplies are landed at Bethel, although some of the smaller vessels will land supplies inside the spit at the entrance to Goodnews Bay, as well as at some points between the bay and Bethel. From Bethel supplies are brought down the river and bay by means of a launch to Kwinak and to Mumtrak, the village in the vicinity of the schoolhouse at Goodnews Bay. Supplies for the Arolic basin are brought from Kwinak either by poling boat in the summer or by dog sled in the winter and early in the spring. For the mining operations on Wattamus Creek, which flows into a tributary of Goodnews River, supplies are taken in summer up the river in poling boats or by kayaks to the landing about 3 miles from the scene of mining operations, where they are transferred to a small scow which is lined and poled up to the camp at Wattamus. In winter supplies may be brought by dog teams from either Mumtrak or Kwinak. The freight rate on general merchandise from Seattle to Bethel in 1919 was $35 a ton, from Bethel to Mumtrak 2 cents a pound, and from Mumtrak to Wattamus Creek 5 cents a pound.

A monthly mail service was in effect from Holy Cross to Bethel and from Bethel to Kwinak during the summer of 1919. Contracts had also been let for a monthly winter service from Kwinak to Togiak by way of Goodnews Bay. In addition to the regular service thus afforded mail is put on such schooners as sail from Seattle for the Kuskokwim. A schooner, already mentioned as carrying supplies, was also intrusted with the mail and left Seattle in July, but had not reached Bethel when the Survey party left that place in September. In addition to mail service a monthly passenger service is afforded by the trips of the mail carrier from Holy Cross to Kwinak and return, his launches and boats providing the most comfortable way of crossing the portage.

CLIMATE.

A Weather Bureau station has already been established at the schoolhouse at Mumtrak. Owing to the short time during which this station has been in operation relatively few meteorologic data are yet available. During the early part of the season of 1919 the prevailing winds were westerly or southwesterly; later in the season easterly and southeasterly winds were more common. Surveys during the season were greatly hindered by stormy and foggy weather,

and on many days when it was nearly clear fog on the hills on the south side of Goodnews Bay and at the head of Goodnews River added to the difficulties of the topographic work. As a rule two or three fair days were followed by a much longer period of cloudy and stormy weather, during most of which no work could be undertaken. In spite of the considerable amount of fog and rain it seems likely that the year's total rainfall is not over 25 inches. Summer temperatures are mild, and it is probable that in general the conditions throughout the year average but little different from those at St. Michael, for which weather records are available, although it may be that periods of storms are slightly more frequent in the Goodnews Bay region. The vegetation differs but little in nature and amount in the two areas.

The snowfall during the winter does not appear to be excessive, but the snows drift badly and accumulate in sheltered spots, so that in some of the valleys it is July before the creek beds are clear. Snow was to be seen in drifts on the north sides of the mountains in gradually diminishing patches as the summer progressed, but in a number of places a small amount of snow lasts from one year to the next.

It is said that the lower Kuskokwim and the bay are usually clear of ice in the middle of May and that the river does not freeze over until about the last week of October. In late seasons ice may remain inside of Cape Newenham until the 1st of June.

VEGETATION.

From Cape Newenham to Apokak, a few miles below Eek Island, at the north end of Kuskokwim Bay, neither trees nor bushes are seen along the shore. North of the area under discussion, from Apokak to Bethel, the banks of the Kuskokwim show scrubby alders at first, followed by larger and larger alders, which are gradually interspersed with some of the larger varieties of willow. The first spruce were seen in the vicinity of Bethel, but they are said to extend for a few miles below that point. Cottonwood appears with the willows. Birch were not seen below Bethel.

Back from the beach, along streams and in sheltered valleys, there are a few willows and alders, which increase in size with the distance from the coast. At Security Cove they are not over 2 or 3 feet high on the slope of the mountains between the cove and Bristol Bay. On Goodnews River 30 miles upstream the willows are from 10 to 15 feet high. Somewhat farther up cottonwood are found along the stream. Where driftwood is not available, the alders and willows are cut and dried for fuel. In drying salmon cottonwood is preferred on account of the fact that it burns slowly and does not cook the drying fish.

A collection of plants, which includes some mosses and lichens, was made during the summer. Approximately 125 species were represented in the collection, which probably comprises the most common flowering plants and grasses but should by no means be considered as completely representing the flora of the region. Wild rye is the most abundant grass at several places near the coast, and it is said that this plant seldom grows far from salt water. One of the botanically interesting localities is the warm, dry rocky southward-facing slope of Beluka Peak, on the north side of Goodnews Bay, where the yellow poppies grow abundantly and the blue forget-me-nots are somewhat less conspicuous in the floral assemblage. The wild rose was not found in the Goodnews Bay region, the first specimen seen on the Kuskokwim being at the mouth of Tuluksak River in August. It is likely, however, that the rose occurs farther down the Kuskokwim, probably being about coextensive with the spruce. One of the common grasses of the marshes was the so-called cotton grass (*Eriophorum*), the white tufts of which usually served as a warning of soft footing.

Berries are neither so plentiful nor so varied in this region as in the interior regions of Alaska, although blueberries and dwarf cranberries grow fairly abundantly in a few localities. The soft, pulpy yellow salmonberry is widely distributed, though nowhere abundant, and the dwarf arctic raspberry is rather uncommon. Red raspberries and currants were not noted.

Perhaps the plants of chief economic interest in this region are the lichens and mosses, upon which the reindeer feed. The caribou moss appears to be the most abundant. These plants cover practically the entire area, as the willows and alders together occupy relatively small areas, and many of the brushy areas contain considerable reindeer pasture. The grasses that occur very commonly in close association with alders along hill slopes and drainageways are said not to be eaten by the deer, except while they are tender, early in summer.

Agricultural operations are seldom carried on by the natives and in 1919 were limited to small gardens, in which a few of the hardier vegetables were grown. A so-called wild rhubarb was also used as a substitute for rhubarb. In general there appeared to be better soil and vegetables grew better at Bethel than at Kwinak or Goodnews Bay.

ANIMAL LIFE.

Although at certain seasons of the year various forms of animal life are abundant in this region, at other seasons parts of the region are practically deserted. There is very little large game. Bear Creek is said to have been named from a brown bear seen there several years ago. It appears likely that in former years caribou were

also found in this region, but if so they have been either killed or driven away and are now supplanted by the herds of reindeer (generally called deer), from which there are occasional strays. The open country, relatively free of brush and timber, and the comparative freedom from flies and mosquitoes combine to make this region especially suitable for reindeer pasture. In winter pasture is afforded on the ridges, from which the snow is blown.

Reindeer to the number of 300 or 400 are said to have been brought to the Kuskokwim about 1904, and an estimate made in 1919 placed the number then at about 15,000. Several hundred deer are owned by the Government and cared for by the Bureau of Education. Sale of female deer from Government herds may be made only to natives. A considerable number of natives are deer owners, and individuals hold from one or two to several hundred each. Several hundred deer are also owned by the Moravian mission of Kwinak and Bethel. The ownership of the remainder of the reindeer was originally vested in the Lapps, who accompanied them as herders and instructors of the natives in herding on the introduction of the reindeer into this region, the deer having been given to these herders at that time. A large part, if not most, of these have recently been purchased with a view to the commercial development of the herds and the shipping of refrigerated deer carcasses from the Kuskokwim basin.

Fish are fairly plentiful in the streams in this region. Salmon are the most abundant, although the run of the various species of salmon in 1919 was said to be much below normal. Grayling, several varieties of trout, and whitefish are also taken. In winter the natives are said to catch a small blackfish from the lakes in the tundra for use as food.

Rabbits do not appear to be plentiful, but it is reported that they seem to be increasing in number. The list of more common fur-bearing animals includes white and red foxes, mink, and muskrat. Squirrels are caught in great numbers, and the skins are used locally in the manufacture of parkas and other garments. The skins of the reindeer are used both for garments and for sleeping bags and robes. The hair on skins of the reindeer fawn is much finer than that of adults, and these skins are used in making a better grade of garments. Dams or other signs of the presence of beaver were not observed by members of the Survey expedition.

Ducks and geese of several species breed in considerable numbers along the streams and in the marshy places, but cranes are relatively scarce. Curlew and plover were frequently seen on the broad, low ridges, snipe and sandpipers were seen along the shores of the streams, and gulls and terns were seen in large numbers along the rock shores, where, with the cormorants, they appear to nest. Hawks and owls appeared to be somewhat uncommon. A number of smaller land

birds were observed, including but one robin. Four birds seen at a distance were believed to be magpies. Ptarmigan were observed at several places, and it is said that in the last year or two they have increased considerably in numbers, although not yet as abundant as they were several years ago.

INHABITANTS.

In the region between Cape Newenham and Kwinak, the white population was about 25 in 1919. The native population of the same region was probably about 250, including the residents at Kiniginogimut, a village on the largest stream emptying into Chagvan Bay, at Mumtrak, on Goodnews Bay; at Kwinak; and at a small village at the north mouth of Arolic River, as well as a number of single families and individuals scattered over the area. Most of these natives were at Kwinak and Mumtrak, where native schools have been established. The natives are all of Eskimo stock.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

In the Goodnews Bay region the rock units as mapped (Pl. VII) are relatively few in number but nevertheless include a considerable range of types. The sedimentary rocks comprise limestone, argillite, sandstone, and conglomerate, and the metamorphosed equivalents of most of these. A considerable variety of igneous rocks are also found, including basalt flows, dikes that were taken in the field to be andesites, and intrusive granites, with some massive intrusives that are probably intermediate in composition between the granite and the basalt and that have been included with the granites on the map in this report. In addition to these rocks, some of which have suffered deformation, there is a considerable area of more strongly metamorphosed igneous rocks, apparently of a basic type. A large part of the region is covered by unconsolidated deposits of alluvial, glaciofluviatile, and marine origin. It appears likely that most of the unconsolidated deposits were formed by more than one agency.

Limitations of transportation and of time prevented detailed geologic work, and a lack of outcrops increased the liability of error in mapping. As the entire area was covered in a field season of 45 days, during much of which the weather was such as to prevent work, it will readily be seen that there were many square miles which it was necessary to map from a distance on the basis of similarity of lithologic appearance, with regional trends as an additional help in delimiting the different rock units.

Search was made during the season for fossils in the sedimentary beds, but without success, so that no definite age assignment of the rock units can be made. Only the relative age could be determined,

and correlations must be founded on data obtained from fossiliferous beds of similar lithology in regions to the north.

It is believed that the areal distribution of the sedimentary and associated igneous rocks, which have been assumed to be of Mesozoic age, is represented with fair accuracy on the map. The distribution of the limestones and of the metamorphic rocks has been plotted from more meager data and therefore is probably less accurate in detail, nevertheless it is felt that the map represents the distribution of these rocks approximately.

STRUCTURE.

The geologic map indicates the general northeasterly trend of the rocks of the region, and the elongation of areas of consolidated rocks surrounded by areas of Quaternary unconsolidated gravels and sands, mainly in the direction of the strike. Variations of strike occur, however, from nearly east to north, but the strikes are mainly in the northeast quadrant. Where other strikes were seen, they appear to have been produced in the relief of local stresses incident to the major deformation. The dips are mainly steep—from 60° to vertical. Apparently southeasterly dips are prevalent. It is assumed, from the differences in degree of metamorphism, that the rocks on the west side of the region are the oldest. With the younger rocks lying to the east, the general structure of the Goodnews River valley is considered to be synclinal, with the eastern limit of the syncline not exposed in the region, unless the metamorphic rocks of Cape Newenham are considered to mark it. Faulting and minor folding are of common occurrence. The folding is especially noticeable in the area of slates, and the faulting in the more arenaceous rocks and in the basaltic tuffs and flows.

SEDIMENTARY ROCKS.

Limestone and the metamorphosed argillitic rocks associated with it are the oldest sedimentary rocks observed in the region. Some of the limestone beds are 100 feet or even more in thickness, but for the most part the series, as observed, is made up of a number of beds from 10 to 50 feet thick, separated by considerable thicknesses of slate or phyllites. Some schistose rocks seen on the western edge of the region are probably to be considered as the metamorphosed equivalent of these beds. Quartzites were also observed in one place in the series. Locally, basic igneous rocks appear to be intercalated with the upper portion of the limestone and argillite series, but probably many of these are intrusive. The limestones are mainly dark gray but weather nearly white. Abundant white talus débris from the limestone beds gives them an undue prominence and in places conceals the talus and surface of the associated rose-bed and dark-gray slates. Nodular cherts were observed in some of the limestone beds, and other beds are reticulated with quartz and calcite

veins. Overlying the limestones is a thick series of argillite sandstone and graywacke, locally metamorphosed to slate and quartzite. The best exposures were observed on the north shore of Goodnews Bay at Beluka Peak and eastward toward the mouth of Tunulik River. At Beluka Peak the rocks are fine-grained, dense, somewhat siliceous argillites of a general gray-green color, which ranges through several shades from nearly white to a slaty drab. These argillites are much shattered and fractured, so that they seldom break along bedding planes. They show much minor faulting, with a lateral displacement across the bedding which may amount to but a few inches or may be several feet. Some bedding planes are slickensided and are thus apparently planes of movement. Calcite veinlets appear along many of the openings produced by movement and also are to be noted in the fractured argillites, some of which are calcareous. There is a thickness of 700 feet or more of argillites underlying a 300-foot bed of sandstone, which grades into a 100-foot conglomerate bed. Alternating and intergrading sandstones and conglomerates to a total thickness of 700 or 800 feet lie above the first conglomerate. The larger pebbles of the conglomerate are mainly red cherts, of which some of the flat, elongated boulders are 2 feet in maximum dimension, but the greatest diameter of the rounded cobbles is little over 1 foot. Green and black siliceous argillite pebbles are also present in these conglomerates. The cementing material is fine green, gray, and black sand.

To the east along the beach from the conglomerates there is an abrupt change in strike from N. 50° E. to N. 25° W., and the rocks are of finer grain, black argillites being succeeded by lighter-colored siliceous argillites which do not have the greenish tinge of those at the western edge of Beluka Peak. The lighter-colored argillites are much netted with fine calcite veins and strike about N. 5° E. These rocks are succeeded by a red and green fine-grained chert or tuff, muck like that in the vicinity of Arctic Island, on the lower Yukon near Russian Mission, which extends for several hundred feet to the east, and give way in turn to a series of basaltic tuffs and flows that crop out for 1,500 feet along the beach.

Although most of these rocks have an easterly dip, the dip is very steep, and in addition there has been considerable faulting, so that while it is believed that, as already stated, younger rocks lie successively toward the east, there appears to be a possibility that at Beluka Peak the rocks are successively younger toward the west, the beds being overturned, and, therefore, that the sequence is from the red and green cherts or tuffs and black slaty argillites through the sandstones and conglomerates to the greenish argillites, and that the pebbles of red chert in the conglomerate were derived from the chart or tuff series.

East of the basalt tuffs and flows argillite and basalt alternate in several wide bands, the next to the last of which, consisting of basalt, extends for 6,000 feet along the north shore of Goodnews Bay, to the mouth of Tunulik River. From the strike and dip of the flows, where observable, it has been calculated that this band represents a thickness of at least 2,400 feet.

At a number of places along the beach on the north side of Goodnews Bay small dikes, from a few inches to 5 feet in width, cut the basalt and the sedimentary rocks just described.

Elsewhere in the area outcrops of sedimentary rocks were observed, but these were of small extent, and usually but few data, aside from the strike, could be obtained from these isolated outcrops. They exhibited all the phases already described, from black slaty argillites to conglomerates, and included at numerous places fine-grained feldspathic graywackes, which were not always readily separable from the basalts. Cherty rocks appeared to be more abundant elsewhere than on Goodnews Bay, especially between Wattamus and Bear creeks.

IGNEOUS ROCKS.

Between Cape Newenham and Chagvan Bay occur altered igneous rocks of a number of types, with minor amounts of slate. The igneous rocks appear to be mainly basic rocks, almost entirely altered to chlorite and serpentine. Some of the serpentine is apparently the source of a white kaolin or asbestos, said to be obtained from a narrow band between Cape Newenham and Security Cove and used as a white paint by the natives. The basic rocks have been cut by later intrusives which appear somewhat more siliceous. North of Cripple River, and again north of Jacksmith Creek, acidic intrusives appear in close association with the limestone.

The basaltic rocks, which may include some andesite intrusive masses and flows, are widely distributed throughout the valley of Goodnews River, and include tuff, thin-sheeted ellipsoidal flows, and thicker and more massive flows. Their occurrence with the argillites and sandstones and their relation to those rocks have already been noted. At Red Mountain the suggestion of columnar structure seen from a distance was considered as showing the probability that the rocks there are also basalt.

This series of rocks is intruded by a number of small batholithic granite masses at the head of Tunulik River, at the head of Granite Creek, on Olympia Creek, and on Arolic River. It is very probable that there are many other intrusive masses in the mountains that extend northeastward and form the divide between the Goodnews and Arolic drainage basins. The andesite dikes seen on the north shore of Goodnews Bay are not improbably related in origin to the intrusion of the granites.

The last major deformation of the region and the present structure were probably caused by the intrusion of the granites, which are also assumed to have produced the auriferous mineralization. Later movements have taken place, but not in such a manner as to produce folding.

TERTIARY AND QUATERNARY GEOLOGIC HISTORY.

It is to the cycle of events occurring within the Tertiary and Quaternary periods that the region owes its present topographic form. To these events also are attributed the unconsolidated deposits now found so extensively over the region. It may be assumed that the intrusion of the granites and the consequent elevation of the land surface occurred at the end of the Cretaceous period or during early Tertiary time. This uplift resulted in a range which extended from what is now the mouth of Kuskokwim Bay northward to Kuskokwim River. The highest peaks of this range were undoubtedly many hundred feet higher than the present crests, and its western front was also far to the west of its present position and faced an open sea much deeper than the present Kuskokwim Bay and Bering Sea, with only a few if any islands in what is now the Yukon-Kuskokwim delta region.

The wave erosion caused the shore line to retreat gradually eastward until it reached approximately its present position. In the meantime the débris from the rapidly cutting streams had been carried to the sea and there transported to form the offshore deposits which shoaled up the waters in late Tertiary time. Mature topographic forms with wide valleys were developed by the beginning of the Quaternary period. During early Quaternary time there appears to have been much extravasation of basaltic lavas in western Alaska. None of these relatively recent lavas are known in this region, though they appear to occur on Bristol Bay and on the lower Yukon in the vicinity of Russian Mission, as well as farther south in the Ingakslugwat Mountains, in the delta region, and still farther south on Nelson and Nunivak islands. It is extremely probable that these outpourings of lava in other regions were marked by changes of level in this region, so that there appears to have been subsidence in the vicinity of Goodnews Bay. In view of the fact that the area probably then stood somewhat higher above the sea than at present, the subsidence that took place appears to have amounted to at least 300 feet. Probably soon after partial emergence glaciation in the region reached a maximum. Glaciers filled many of the interior valleys but appear not to have reached the sea except in a few places, as in the valley of Goodnews River and possibly also by way of Chagvan Bay. With the retreat of the glaciers a great amount of glacial débris was deposited in the streams, which were taxed to their limits

to transport the material to the sea. Their task appears to have been made easier by further elevation of the land surface, but at the first opportunity their load was dropped, and thus was built up the widespread frontal tundra-covered gravel coastal plain which now lies between the mountains and Kuskokwim Bay and River. Some of the materials laid down in the upper portions of some of the streams, where their valleys were marine embayments, are now being reworked and transported to the sea. Examples of such reworked material are afforded by high gravels overlain by silts in the valley of Goodnews River. In verification of this hypothesis as to the mode of origin of the frontal apron of the mountains, it may be pointed out that the indentation of the shore line called Jacksmith Bay is opposite a stretch of mountains from which no large streams flow, while on either side the shore line has been extended westward through deposition by streams. At the present time the westward advance of the shore line seems to be practically at a standstill, and it is probable that in this particular embayment, owing to the fact that the shore is made up of fine silt and peaty material and is unprotected by a gravel beach, as it is to the north and south, the shore line is shifting slowly eastward. Streams entering the other bays are filling them and extending the land area, obtaining their débris through all the forms of erosion prevalent in subarctic climates, including mechanical disintegration by frost, nivation, and soil flows, as well as normal transportation by running water.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

A summary of the history of mining in the Goodnews Bay region has been given by Maddren[1] in connection with his report on the results of field work in 1914. In his discussion he considers the entire valley of the lower Kuskokwim, including the Goodnews Bay region:

> This region appears to have been neglected as a field for prospecting during the early years of the gold excitement that centered in the Klondike and spread along various tributaries of the Yukon. It was not until the Nome boom, in Seward Peninsula, reached its height during 1900 that further attention was directed toward the Kuskokwim region. One of the results of the rush of people to that district was the movement of a small number of men from Nome to the region about the mouth of the Kuskokwim during the summer of 1900, and they prospected in that vicinity for several years. Placer gold was discovered at several localities in the vicinity of Goodnews Bay, and productive mining on a small scale was undertaken on Butte Creek, in the basin of Aalalik [Arolic] River near the settlement of Quinhagat [Kwinak], and has been carried on for the last 10 years or more.
>
> During the winter of 1900–1901 a typical dog-sledge stampede to the Kuskokwim Valley was made by a considerable number of men from Nome. The

[1] Maddren, A. G., Gold placers of the lower Kushokwim: U. S. Geol. Survey Bull. 622, *pp. 299–301, 1915.*

movement was based on vague rumors of the discovery of placer gold on a stream designated "Yellow River," but the location of this stream in the Kuskokwim Valley does not appear to have been even approximately fixed.

From 1901 and 1902 there appears to have been some mining done on the Arolic, but with the failure to find bonanzas the majority of the stampeders left this field, and it was not until 1906 that there was another influx. Maddren continues:

The discovery of placer gold on the headwaters of Innoko River in 1906 caused a considerable movement of prospectors from Nome up Kuskokwim River the following year. It is estimated that several hundred persons left Nome for the Innoko diggings by way of the Kuskokwim River during 1907. Most of them arrived at their destination after various delays and risks due to unsatisfactory transportation, especially across Bering Sea and into the mouth of the river. A few of these persons, however, did not go all the way to Innoko district but stopped at various points along Kuskokwim River and turned their attention to prospecting some of its tributaries.

The "mosquito flotilla" that came up the Kuskokwim in 1906 and 1907 made it appear to the traders and missionaries at Kwinak and Bethel as if they were no longer on the outskirts of civilization, with but one or two yearly boats bringing supplies, but were on one of the world's commercial highways.

Each influx of prospectors was encouraged by the finding of gold in the streams they prospected, but after working for a time most of them failed to develop profitable ground and left. However, a small production by a few men continued to be made yearly on Butte Creek, and some mining was done on Fox and Snow gulches and on Trail, Kowkow, and numerous other creeks. An estimate of $100,000 for the total production to 1919 was based on an estimate of $70,000 for Butte Creek and $30,000 for the streams named, all of which flow into the Arolic or one of its tributaries. Of the $30,000 a considerable proportion came from Kowkow Creek. The first production of gold on this creek was made in 1913, and a number of claims on it have been held ever since.

Practically every white man in the region has had at some time during the last three years an interest in one or more claims in the Arolic basin. Some have utilized these claims to get a grubstake on which to prospect during the spring, and in 1917 a party of three or four men were engaged in prospecting on Bear Creek, which flows into Canyon Creek, a tributary of Goodnews River, when a native reindeer owner and herder called Wattamus (apparently a corruption of his baptismal name Bartimeus) reported to one of the miners that he had found gold on a stream about 8 miles to the south. Several claims were staked on this new creek, which was named Wattamus after the discoverer. After staking, the owners of Discovery claim and the two claims above and the two below

Discovery pooled their interests, and these five claims have since been held as a unit. Later comers staked ground above and below the Discovery group. A notable production was made during 1917 on the Discovery group of claims, and in 1918 considerable mining was done. The total production for the two years was about $35,000, thus giving an approximate total for the district, prior to 1919, of $135,000.

In addition to the streams above mentioned as having been producers, many others have been prospected. Some of the streams in the vicinity of the granite masses showed fine gold but not in sufficient amount to warrant the undertaking of mining, and for the most part titles to claims have been allowed to lapse.

GOLD PLACERS.

GENERAL FEATURES.

There are in general two types of placers in the Goodnews Bay region. Those of the Arolic basin are mostly in wide gravel-filled valleys in the group of low hills in the vicinity of Butte Creek or between these hills and the surrounding hills or mountains to the south, east, and northwest. The placers of the Goodnews Bay drainage basin, on Wattamus and Bear creeks, are in much more sharply incised valleys in the mountain masses. The Arolic placers probably represent concentration from older valley fillings, glacio-fluviatile or marine sediments; the others represent the concentration of gold by erosion of bedrock since glaciation, in the bottoms of glacial valleys.

The streams that yielded gold in 1919 were Kowkow, Wattamus, and Bear creeks, the first in the Arolic Basin, the others in that of Goodnews Bay. In the Arolic Basin title to claims in Butte and Trail creeks is held pending future developments and operations. A number of claims in addition to those worked are also held on Kowkow Creek. On Wattamus Creek several claims are held below the Discovery group with a view to the possibility of developing dredging ground.

MINING CONDITIONS.

Inasmuch as the placer ground is shallow, open-cut mining is the method in use. An effort is made to groundsluice off as much of the overburden as possible, usually within a foot or two of bedrock, before shoveling in. At times there is a shortage of water for groundsluicing, but this difficulty is partly overcome in various ways. On Wattamus Creek a dam has been erected to impound water which is used for "splashing." On Kowkow Creek ditches bring the water from the forks of the creek. It is said that more mining could be done on Butte Creek were water available, but the necessity of constructing ditches to bring water will mean one or two seasons of dead work before mining can be done with other than Butte Creek water.

The conditions of snowfall and the time of melting of the snow vary on the different creeks, but it is late in June or even July before the creeks are sufficiently free of snow and frost to permit ground-sluicing, which it is aimed to do while the water is abundant. The later part of September is as late as mining can usually be carried on, although in favorable years the mining season may extend into October. Most of the auriferous stream gravel as well as the barren gravel overburden lies within the reach of circulating water, and operations are therefore not impeded by the necessity for thawing. However, large granite boulders in the gravels on the upper claims of Wattamus Creek are a very real detriment to mining. It is probable that such boulders will also be found on the upper courses of other streams heading from either side against the Arolic-Goodnews divide.

Most operations are conducted on a partnership basis, but the Discovery group of claims on Wattamus Creek were being worked by about 10 or 11 men. Wages in 1919 were $6 and board for an 8-hour day. Labor is difficult to procure, for a number of the permanent residents have ground of their own which they work more or less intermittently, and as this district is off the main highway of Alaska travel, the Yukon, there is little opportunity of obtaining labor from the drifting class of miners.

As no power plants were in operation in 1919 and there is no necessity for thawing, fuel was required only for camp purposes. It was obtained by gathering and stacking alders and less preferably willows, which were used after a period of drying. In the vicinity of the camp both alders and willows are found in sufficient numbers to meet immediate needs.

There is no spruce timber in this region nearer than Bethel, so that lumber for sluice boxes must be obtained from the sawmill at that place or by whipsawing drift logs from the upper Kuskokwim found on the beach, chiefly in the vicinity of Carter Spit. Spruce, however, is not wholly satisfactory, and whenever possible lumber is obtained from the States. Cottonwood grows on the upper Goodnews River; and cottonwood poles, together with a few large alders or willows, are sometimes used to make the trestles of the sluice boxes.

ORIGIN OF THE PLACERS.

The principal rocks throughout the region are those of sedimentary origin, including sandstone, quartzite, slaty or argillitic rocks, chert, and limestone. Associated with the sediments are lava flows, in large part basaltic. These rocks are intruded at a number of places by granitic and related acidic rocks. It is believed that these intrusives have caused most of the auriferous mineralization of the sedimentary rocks. Quartz veins are not uncommon, but they are mainly narrow and of small extent, so that quartz pebbles and cobbles are rather rare. It is believed that some of these veinlets carried the gold from whic'

the placers were derived. This hypothesis accords well with the known facts with respect to Wattamus Creek and to some of the other streams that head against granite areas and are reported to carry gold but not in quantities sufficient to pay for mining.

No acidic igneous rocks were observed in the immediate vicinity of the placers on Bear Creek, nor were pebbles of this type of rock observed in the gravels in the cut on this stream. It would thus appear that the placer gold is derived mainly from veinlets that were probably related in origin to the intrusive granite found elsewhere in this region. So far as known, the placer ground on this creek is all of low grade, and those who worked on it in former years report that they could not make wages on it.

Some massive intrusives occur in the Kowkow Mountains, south of Kowkow Creek, and between the crest of the ridge and Kowkow and Trail creeks there is much quartz veining in the severely fractured rocks. No gold was observed by the writer in any of the quartz veins. Between Kowkow and Butte creeks the bedrock is covered by a mantle of unconsolidated gravels which is locally as much as 75 feet thick. A few outcrops of shattered limestone appear, however, rising slightly above the gravels. Associated with the limestone at the head of Butte Creek are andesitic rocks which are apparently intrusive and which may have had an influence on the occurrence of the gold.

The valleys of Wattamus and Bear creeks were once occupied by glaciers, and any preglacial concentrations of gold were swept out and disseminated in the valley of Goodnews River. The present gold placer deposits of those streams are concentrations of the gold contained in the rocks which have been cut down by erosion since the glaciation. Erosion has been rapid since the retreat of the glaciers and has consisted of rapid mechanical disintegration by frost, assisted by soil flows, which have carried the disintegrated rock from the slopes to the bottoms of the valleys. Thence it is removed by the normal processes of stream transportation so far as the streams are competent to transport the soil and rock débris.

For the deposits worked in the Arolic basin the mode of the later concentration into workable placers is not so readily apparent, as the physiography of that area involves other factors in addition to those concerned in the concentration processes on Wattamus and Bear creeks, and the history of the area has by no means been completely deciphered. It was not possible to determine whether the accumulation of the placers on Butte and Kowkow creeks was preglacial or postglacial, although the so-called gumbo bedrock on Kowkow Creek resembles a reworked till. As has been stated in the consideration of the geologic history, the land surface once stood at a higher level than at present, was then depressed, probably 300 feet or more below the present surface, and was then reelevated to approximately

its present position. The maximum glaciation possibly occurred shortly after the period of maximum inundation and before reelevation to the present level was completed. During the period of these earth movements deposits of gravel were formed by normal stream erosion, by the deposition of glacial débris, by wave action along beaches, and by combinations of these three processes. On reelevation of the surface to approximately its present position, normal stream erosion was resumed in the gravel deposits, and in places the underlying bedrock was cut. The Arolic deposits are therefore due to stream concentration from bedrock and from the probably auriferous gravels that had been previously accumulated.

MINING OPERATIONS.

During the summer of 1919 all the creeks on which mining was being done were visited, and some notes were made as to details of mining methods and other features in connection with the operations.

WATTAMUS CREEK.

Placer gold was discovered on Wattamus Creek early in the summer of 1917 by a native who was herding reindeer in the vicinity. He reported the discovery to a group of miners on Bear Creek, who returned with him and staked Discovery claim and Nos. 1 and 2 above and 1 and 2 below Discovery, including one claim for the native. Interests were pooled on these claims, and the native and one of the original stakers have since sold out to the Discovery Mining Co., the shareholders of which include Charles Thorsen and Jack Wilkins, who were among the original group of owners. Joe Jean has purchased the shares of some of the others. A number of other claims were staked above and below the original group, but little work has been done on any of these except "No. 3 above." On the discovery of paying ground, work on Bear Creek stopped and operations were transferred to Wattamus Creek, where during the fall of 1917 gold to the value of more than $10,000 was produced. In 1918 work was continued, chiefly on Discovery claim, and the production was more than $20,000, making a total for the two years of about $35,000.

In 1919 work was being done on three claims by two plants. The Discovery Mining Co. employed 10 or 12 men, about equally divided between claims Nos. 1 above and 1 below Discovery, and Ryan & Wickert worked "No. 3 above." In addition to the claims that are being worked, a number of other claims are held, and some of those below the Discovery group were prospected during the winter of 1918–19 with a view to dredging operations.

The width of the so-called pay streak varies greatly; it is probably not over 20 to 30 feet on "No. 3 above" but more than 100 feet

below the Discovery group. Some of the small gulches appear to have greatly enriched the main pay streak, and in a few places there is some rich ground at the sides above the creek level. The value of the gold in the pay streak runs from 25 cents to $2.50 per square foot of bedrock. The gold is reported to assay $16.40 an ounce.

All mining is done by open-cut methods. The material is ground-sluiced to remove 2 to 5 feet or more of barren soil and gravel, leaving from 1 to 2 feet of gravel to be shoveled into the boxes, the larger boulders being rolled to one side. Where the bedrock is loose and friable slate or sandstone, about 6 inches of that is mined also. The bedrock consists mainly of slaty argillite, sandstone, chert, and basalt. The gravels are predominantly of these rocks but contain also pebbles of conglomerate and of a dark-colored porphyritic rock with varying amounts of granite. The granite pebbles increase in size and amount toward their source, at the head of the creek. Below Discovery claim there are relatively few boulders more than 18 inches in diameter; on claim "No. 1 above" they are 3 to 4 feet in greatest dimension but are not so numerous as to constitute a serious impediment to mining. On "No. 3 above" the granite boulders are still larger and more numerous.

From the data at hand it is estimated that the total production of this creek will probably be little over $250,000, unless the lower claims are worked by dredges, for it is doubtful whether the claims below "No. 2 below" can be worked profitably by hand. Boulders would probably seriously interfere with dredging operations above Discovery claim. It is not likely that the ground above "No. 3 above" will pay wages if worked.

BEAR CREEK.

Apparently the first claims on Bear Creek were staked in 1916, although they may have been staked at the time of the early rushes to the Arolic in 1900, 1901, and 1906–7. Little if any work was done until 1917, when a few men were working there. Some of these men working claim "No. 1 above" report that they did not make wages and left for Wattamus when gold was found on that stream. In 1919 two men were working on claim No. 2 above Discovery, the first work that had been done on that claim.

This stream flows into Canyon Creek, a tributary of Goodnews River, and should not be confused with the Bear Creek in the area at the head of the Tuluksak, on which some mining has also been done, nor should the Canyon Creek into which this stream flows be confused with the Canyon Creek that lies between Kanektok River and the Tuluksak-Aniak region.

At the head of this creek a dark-gray fetid limestone appears in the bed of the creek. This limestone appears to grade into slaty cal-

careous argillites. Sandstones, grit, and conglomerate, as well as chert and some basic fine-grained igneous rocks, are also found within the basin of the stream. The rock is not exposed in the bed of the creek where mining was being done, but the gravels are made up of boulders, cobbles, and pebbles of conglomerate, sandstone, limestone, and dense argillite, with a little chert. Some of the boulders are much weathered to a light-yellow rock. They were probably basalts originally. Overlying 2 to 5 feet of gravel is 2 to 3 feet of black, tough clayey muck, over which the stream flows with but little cutting. Some of the gravels are iron stained and partly cemented.

When the creek was visited, August 11, 1919, a cut 15 by 50 feet had been groundsluiced off. The cut was made diagonally across the creek bed, to cut the pay streak, if there was one. No boxes had yet been put up, so that it was not possible to determine the gold tenor of the gravels from the clean-ups. However, two or three pans taken along the base of the gravels each gave only a few very small colors, and it is doubtful whether the cut paid wages.

AROLIC BASIN.

The first mining in the Arolic Basin was done in 1900 or 1901, but little gold was produced until after 1906. The production has come chiefly from Butte Creek. Since work was started on Kowkow Creek in 1913 the yearly production from that stream has probably about equaled that from Butte Creek and in some years has exceeded it. In 1918 a power scraper was operated on Kowkow Creek. In 1919 but one claim was being worked in the Arolic basin, three partners operating on claim No. 1, above Discovery, on Kowkow Creek. Several other creeks in this basin have been prospected, but their entire production is negligible.

Where mining was being done in 1919 about 6 or 7 feet of overburden was being moved. The upper 1 to 3 feet consists of soil, moss, and peat and overlies 3 to 4 feet of nearly black, reddish, or blue-gray uncemented gravel, which, in turn, overlies 8 to 15 inches of rather fine gravel, containing a little clay. This bottom layer is tightly packed and requires considerable picking to loosen, but it breaks up readily in running water. The excavation is carried to a false bedrock, called "gumbo" on Kowkow and Butte creeks, which is a tight clay that contains a very small amount of gravel and somewhat resembles a glacial till. The depth to bedrock is not known. On Butte Creek the depth below the "gumbo" is said to be 15 to 25 feet. The gravels are mostly of local origin and consist of argillite, basalt, sandstone, and some coarser-grained acidic igneous rocks. On Butte Creek limestone gravel is also found. The Kowkow gold is said to assay $17.60 an ounce, and that from Butte Creek somewhat higher.

CONCLUSIONS.

The original deposition of the gold in fissures associated with quartz was probably genetically related to the intrusion of the late Mesozoic granites into the sedimentary and earlier igneous rocks, which range from Paleozoic to probably late Mesozoic in age.

From the original deposits the gold has been eroded by streams and other agencies, not including glaciation, and has been concentrated in placers by some streams, mainly those in the vicinity of the granites.

Glacial erosion has removed most of the gold-placer deposits and has scattered the gold widely over a considerable area in amounts not suitable for profitable mining.

Postglacial concentration has been effected by some streams in connection with the erosion of the rocks containing auriferous veins. In other streams the placers appear to be, at least in part, the result of reconcentration from glacial, fluvio-glacial, and marine deposits. In a general way, both types of deposits may be found in the vicinity of the granites.

COAL.

No coal is known in the Goodnews Bay region, although natives have brought in to the school teachers and others at Mumtrak reports of "a mountain of coal" south of Goodnews Bay. These reports have not been verified, and it appears likely that the supposed coal is a dense black chert or fine-grained black basalt. Small seams of coal are reported to occur on Hagemeister Island and on the beach near the mouth of Kulukak River, on the north side of Bristol Bay. Coal of good quality in thick beds is also said to occur north of the Goodnews Bay region, on Eek River, near what is known as the island mountain, described as an isolated low mountain rising well above the surrounding flats and forming a conspicuous landmark. The occurrence of this deposit seems to be well authenticated.

ASBESTOS.

Along the shore between Cape Newenham and Security Cove there are said to be exposed thin seams or veins of a white material, which is believed to be asbestos of the very short-fibered variety produced by the weathering of serpentinous rocks. It appears to be weathered almost to a clay, so that its commercial possibilities appear small. The natives occasionally obtain small amounts from this deposit and, mixing it with seal oil, use it as a white paint for their kayaks and bidarkas. A red paint obtained near by is believed to be hydrous iron oxide precipitated from water seeping through pyritiferous slate or argillite.

MINING ON SEWARD PENINSULA.

By George L. Harrington.

PLACER MINING.

SUMMARY OF MINING CONDITIONS.

During the summer of 1919 climatic conditions on Seward Peninsula were generally favorable for placer mining until the later part of September and the first few days of October, when a heavy freeze and snow cut off the water supply and necessitated the closing down of most of the plants. A brief thaw a little later permitted resumption of work for a short time, but the greater number of plants were closed down for the winter by the 1st of October, only the dredges and a few of the larger plants continuing mining after that date and most of the latter working with reduced crews. Throughout the winter season the labor situation was not satisfactory, and there was relatively little winter work. In summer the situation improved somewhat, but the 8-hour shift was accepted by a number of operators only with the greatest reluctance, especially where additional labor was not obtainable or other conditions were not such as to make a second shift practicable. At numerous places on the peninsula many of the plants were obliged to work short-handed, and a few used Eskimo labor.

Gold, tin, and platinum were recovered through some of the various methods of placer mining. No information was obtained regarding the saving of scheelite as in previous years as a by-product of placer mining for gold. Difficulty had been experienced in marketing the product in the past, and this, in connection with the labor involved, appeared to make the saving not worth while.

Gold was recovered from most of the operations, and tin (cassiterite) was obtained as usual from the York region, also in small amount as a by-product of gold mining on Goodhope River. Platinum was recovered with gold from the placer operations in the Koyuk and Buckland drainage area.

During the summer work was continued on several projects of direct or indirect benefit to the mining industry. The east jetty of the Snake River harbor was completed, and the channel was dredged to permit the entrance of small schooners to a secure harbor and their

loading and unloading without lightering, an important item in the coastwise transportation of supplies from Nome.

Work was also continued on roads throughout the peninsula, and the Candle Creek road was completed as far as claim No. 16 above Discovery, Candle Creek. At Nome the road was completed to Cape Nome. A road has also been constructed from the landing on the Koyuk to the center of mining operations on Dime Creek.

The Kougarok region appears to have the poorest transportation facilities. At present the main line of transit is the railroad, over which is run the "dogmobile." No repairs have been made on this railroad for several years, and according to reports its state of disrepair makes travel over it hazardous. The need is acute of either the construction of a wagon road or the repair and operation of the railroad to serve the needs of the miners in the Kougarok River and Iron Creek districts.

Under present conditions of operation there is frequently a shortage of much needed repair parts in Nome, as the hardware stores have decreased their stocks to include only the staple and more quickly salable goods. This has worked a very great hardship on some operators when they were in need of castings for repairs. It would appear that this difficulty might be met by the cooperative purchase of a small electric furnace, such as has been installed at Treadwell, for the making of emergency castings, thus doing away with the delay incident to shipment from Seattle. Under conditions of shipping such as prevailed in 1919 this delay may amount at times to a month or more, which may be one-third of the working season.

THAWING OF FROST IN GRAVELS.

For some years thawing has been one of the main problems in connection with the dredging of the low-grade auriferous gravels of the Nome coastal plain. The method of thawing by a series of drainage ditches and laterals in conjunction with natural drainage courses has been described in general terms by Eakin [1] and has received some consideration by owners and engineers in charge of dredging operations. At present consideration is being given to the project of making such a drainage canal to enter Snake River near the mouth of Center Creek. The initial cost and the uncertainty as to the extent of the thawed ground that would result, as well as the divided ownership of the ground, have been the main deterrents to the carrying out of this project and similar large-scale thawing operations.

Standard practice in thawing frozen gravels throughout Alaska and northern Canada has hitherto involved the use of steam. As

[1] *Eakin, H. M.*, Placer mining in Seward Peninsula: U. S. Geol. Survey Bull. 622, pp. 368–369, 1915.

the tenor of the workable gravels has decreased, efforts to lower operating expenses have resulted in changes in details of the process, and each plant has varied the length of points, their spacing, and the time of application of steam. The greatest economies appear to have been effected by decreasing the time during which steam is applied under pressure and allowing a longer period of sweating, thus securing greater thawing efficiency for the heat units applied. Experimental work[2] has proved the possibility of cold-water thawing, and a number of plants have thawed frozen gravel by this method.

In 1919 cold-water thawing was used by three dredges on Seward Peninsula. On Candle Creek the Candle Creek Mining Co.'s dredge pumped water to a tank on the hillside, giving it an opportunity to warm up somewhat before being used in thawing. An even pressure was also insured by this method. In the Council region ditch water under head was used. At Nome the Alaska Mines Corporation thawed ground in advance of dredging on Flat Creek by cold water, obtaining pressure by pumping direct to the points. It is probable, however, that this company will utilize ditch water under a head, instead of pumping. Two dredges in the Iditarod district also used cold water for thawing.

Details of the processes used at all these plants are not at hand, but at the plant of the Alaska Mines Corporation, Nome, the temperature of the water used for thawing was about 55° F. It left the frozen ground at a temperature of about 34° or 35° F. After the ground is thawed the temperature of the water as it leaves is practically the same as that at which it enters. The maximum thickness of gravels thawed in 1919 was 42 feet, with as much as 20 feet of clayey material. It was stated that no trouble from unthawed blocks was experienced throughout the summer in the dredging operations. Points were spaced 10 feet on centers and left in for 7 days, and a pressure of 25 pounds was maintained by pumping. In shallower ground, 7 to 10 feet deep, at Council, where ditch water was used, points spaced 5 feet on centers were left in 48 hours.

GOLD.

Placer gold is recovered on Seward Peninsula by dredging, by underground mining, and by open-cut work including shoveling in, the use of the hydraulic giant for stripping and mining, the use of the hydraulic lift, and the use of the open hydraulic lift on the Ruble elevator. In addition to the plants engaged in producing gold, a number were doing preparatory work, such as the construction of ditches and the stripping of barren surface material from the auriferous gravels to be mined later, and in prospecting. The prospecting was mainly in the nature of proving ground already held, rather than

[2] Cathcart, S. H., Mining in northwestern Alaska: U. S. Geol. Survey Bull. 712, pp. 190-194, 1920.

a search for new deposits. In general, relatively little new development of unproved ground was attempted, mainly on account of legislation permitting the holding of title to claims without the doing of assessment work.

DREDGING OPERATIONS.

During the summer of 1919 a total of 22 gold dredges were in operation for varying periods, as compared with 21 in 1918. They were distributed as follows: Nome district, 7; Council district, 8; Solomon district, 4; Kougarok, Fairhaven, and Port Clarence districts, 1 each. A number of other dredges were idle for various reasons, chiefly on account of reconstruction or moving to other localities. Some were idle, however, while additional areas were being proved or prepared for dredging. In the Nome district the Alaska Mines Corporation operated one dredge on Flat Creek, but the other dredges of this company were idle, though some were undergoing repairs and reconstruction. James Bellevue was rebuilding a dredge on Dry Creek. The Bangor and Hastings Creek dredges, operated in 1918, were idle in 1919. Included in the list of dredges in the Nome district is that operated by William Rowe on Snake River, primarily for the purpose of deepening the channel of the river as a part of the Nome harbor project; but the dredge was also operated to save the gold content of the gravels handled.

In the Council district the Crooked Creek and Melsing Creek dredges were again working. The Moody Mining Co.'s dredge was idle, but the company expects to operate this dredge in 1920. Changes contemplated for 1920 include moving the Elkhorn dredge (G. & O. Dredging Co.) to Warm Creek and the Camp Creek dredge of the Uplift Mining Co. to Golofnin.

At Solomon four dredges were operating, as compared with five in 1918, the Scott & Newburg dredge being idle. One of the Kimball dredges was dismantled for shipment to Kuskokwim River. This dredge was in Seattle late in 1918, awaiting transportation.

During the summer of 1918 the Kelliher dredge in the Kougarok was idle, the owners being engaged in stripping ground for future operations. In the Port Clarence district, neither the Dobson dredge nor that of the Alaska American Gold Mining Co. (Bernard dredge) has worked regularly since 1917. During the summer of 1919 prospecting was being done by the owners of the Dobson dredge, with a view to the resumption of operations. A dredge reported to have been brought from Serpentine River was being reconstructed on Sunset Creek, near Teller, and is said to have been operated for a short time late in September and early in October. In the Fairhaven precinct only one dredge was operating, that on Candle Creek. Low water in the spring again prevented the movement of the *Iver Johnson* dredge from the Kugruk to Candle Creek. The dredge on the *Inmachuk* was idle also.

It is reported that on Bonanza Creek, a tributary of Ungalik River, at the base of Seward Peninsula, dredging ground was purchased and some development work was done upon it.

The following is a list of gold dredges operating in 1919 on Seward Peninsula, in addition to which two tin dredges were also working in the Port Clarence precinct:

NOME DISTRICT.

Dexter Creek Dredging Co	Dexter Creek.
Arctic Creek dredge	Arctic Creek.
Center Creek Dredging Co	Snake River.
Wm. Rowe	Snake River.
Guinan & Ames	Glacier Creek.
Julien Mining Co	Osborn Creek.
Alaska Mines Corporation	Flat Creek.

COUNCIL DISTRICT.

Fernegal & Hanson dredge	Crooked Creek.
Wild Goose Mining & Trading Co	Ophir Creek.
Blue Goose Mining Co	Ophir Creek.
Northern Light Mining Co	Ophir Creek.
G. & O. dredge (formerly Elkhorn dredge)	Niukluk River.
Uplift Mining Co	Niukluk River.
Flume Gold Dredging Co	Melsing Creek.
Adams & Wik	Goose Creek.

SOLOMON DISTRICT.

Eskimo Dredging Co	Solomon River.
Shovel Creek Gold Dredging Co	Solomon River.
Flower dredge	Solomon River.
Burners, Iverson & Johnson dredge	Big Hurrah Creek.

KOUGAROK DISTRICT.

Behring Dredging Co	Kougarok River.

FAIRHAVEN DISTRICT.

Candle Creek Mining Co	Candle Creek.

PORT CLARENCE DISTRICT.

Dr. Andrews	Sunset Creek.

Most of the dredges use distillate for fuel, though some are using crude oil. A number of dredges are equipped with internal-combustion engines, and a few have been equipped for electric operation, including the Wild Goose dredge at Council, which obtains hydroelectric power generated by ditch water, and the Flat Creek dredge at Nome, which obtains its power from a steam-driven turbo-generator fired with fuel oil.

During the summer of 1919 a representative of the company that is planning to develop hydroelectric power from a plant in the Kigluaik Mountains was in Nome making a survey of potential power

users on Seward Peninsula. Should it prove feasible to develop power from this source, at a reasonable cost, the plant should solve the often difficult problem of fuel for the dredges of the Nome, Council, and Solomon districts and should prove a potent factor in the dredging of the large areas of low-grade auriferous gravels in the vicinity of Nome.

It is estimated that the 22 gold dredges on Seward Peninsula in 1919 employed 183 men and had a gold yield of $450,000, compared with a yield of $469,000 by 21 dredges in 1918.

UNDERGROUND MINING.

There was a very notable decrease in both underground and open-cut mining on Seward Peninsula during 1917 and 1918, and this decrease continued in 1919. It is to be attributed to a number of causes. The high-grade placers, which can be mined profitably by small-scale operations, are gradually approaching exhaustion. Those that are not exhausted are being consolidated into larger holdings, to be mined more economically by larger operations extending over a period of years. The increased cost of practically all supplies, of transportation, and to a lesser extent of labor have made unprofitable the mining of much ground which could formerly have been worked at a profit. The higher wages paid in the manufacturing industries in the Western States for the labor formerly employed, much of it skilled or semiskilled, have attracted and held many of those formerly engaged in mining, so that there is an actual shortage of labor for the mining industry. As a result there are fewer men engaged in the search for and development of new deposits during those seasons of the year when relatively little mining is being done.

In 1919 about 17 deep placer mines were worked in Seward Peninsula. It is estimated that 10 mines were worked during the winter and 7 in the summer, employing about 78 men. The operations so far as known were distributed as indicated in the following list:

Deep placer gold mines worked on Seward Peninsula, 1919.

	Number of mines.	Men employed.
Nome district	4	10
Fairhaven district	7	28
Koyuk district	6	40
	17	78

By far the largest part of the production from the deep placer mines was made during the winter, and operations of this type were relatively less productive in the summer of 1919; moreover, there were fewer mines in operation.

OPEN-CUT WORK.

In the summer of 1919, 74 open-cut mines, including 24 hydraulic plants, were operated, employing an approximate total of 332 men. Operations were distributed by districts as follows:

Open-cut gold placer mines on Seward Peninsula, 1919.

	Hydraulic plants.	Other open-cut operations.	Men employed.
Nome district	9	8	140
Solomon district	4	1	13
Council district	2	1	21
Kougarok district	4	18	42
Fairhaven district	5	10	81
Port Clarence district	....	7	14
Koyuk district	....	5	21
	24	50	332

Included in the list of hydraulic operations are the plants using Ruble elevators on Bear Creek and at Candle, in the Fairhaven district. Two plants in the Nome district and one on Inmachuk River used hydraulic lifts. Under "Other open-cut operations" are placed three plants, two of which were engaged in the preparation of ground for dredging and one in the construction of a ditch preparatory to mining.

PRODUCTION.

There were 91 gold placer mines and 22 gold dredges operated on Seward Peninsula in 1919. Approximately 550 men were employed in these operations, and the production is estimated at $1,400,000.

Gold and silver produced on Seward Peninsula, 1897–1919.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1897	725.63	$15,000	87	$52
1898	3,628.12	75,000	435	256
1899	135,450.00	2,800,000	16,254	9,752
1900	229,781.25	4,750,000	27,574	17,097
1901	199,822.61	4,130,700	24,579	14 747
1902	220,677.07	4,561,800	26,481	14,035
1903	215,994.38	4,465,000	24,171	13,052
1904	201,462.52	4,164,600	24,175	14,021
1905	232,200.00	4,800,000	27,864	16,997
1906	352,812.50	7,500,000	43,537	29,605
1907	338,625.00	7,000,000	25,497	16,828
1908	247,680.00	5,120,000	20,577	10,905
1909	207,077.50	4,280,000	20,871	10,853
1910	169,312.50	3,500,000	20,317	10,971
1911	149,962.50	3,100,000	17,996	9,718
1912	145,125.00	3,000,000	17,415	10,710
1913	120,937.50	2,500,000	12,094	7,305
1914	130,612.50	2,700,000	15,673	8,667
1915	140,287.50	2,900,000	17,510	8,878
1916	142,706.25	2,950,000	14,271	9,391
1917	125,775.00	2,600,000	13,770	11,346
1918	53,599.50	1,108,000	6,022	6,022
1919	65,790.00	1,360,000	6,940	7,773
	3,830,044.83	79,360,100	424,110	258,981

TIN.

The dredges of the American Tin Mining Co. and the York Tin Dredging Co. were both in operation in 1919, the American on Buck Creek and the York on Grouse Creek. Three men were engaged in shoveling into sluice boxes on Buck Creek above the dredge. A total of 25 men were engaged in tin mining, and the production was about 56 tons.

In addition to the recovery in the York region a few hundred pounds of tin concentrates were saved in connection with gold mining on Humboldt Creek, a tributary of Goodhope River. These concentrates were not shipped in 1919.

PLATINUM.

In 1919, as in previous years, platinum was recovered with the gold on Bear, Dime, and Sweepstakes creeks at the base of Seward Peninsula. The production was probably about 20 ounces.

LODE MINING.

There was relatively little lode mining on Seward Peninsula in 1919. Assessment work was done on a few properties, and title to other claims, on which no assessment work was done, was maintained by the filing of the necessary affidavits.

GOLD.

One gold lode mine near Bluff is said to have operated during the winter, and the ore mined was milled during the summer by means of water power.

TIN.

A crew of about 12 men is reported to have worked at the tin mine on Lost River during the winter of 1918-19, and about 25 men during the summer. The winter work consisted mainly of retimbering, enlargement of drifts and shafts, and deepening of shafts. A number of buildings were erected, and a compressor plant was installed to furnish air for drills and for ventilation. A large warehouse was also built on the beach at the mouth of the river. A considerable shipment of mining machinery and supplies for this property was unloaded at the mouth of Lost River from the freighter *Cordova* in October, 1919.

SILVER-LEAD.

The silver-lead prospect on Kugruk River near Independence Creek was further developed during 1919, a crew of 6 to 14 men working throughout the year. The work appears to have consisted mainly in sinking the shaft. Data regarding the amount of lateral development are not at hand. A considerable amount of ore has been mined during the development work but has not been shipped

owing to difficulties of transportation. An effort is said to have been made to get a shipment of ore down the Kugruk in small scows. Low water during the spring when a high stage was expected prevented these boats from getting down the river. Additional development work was to be done during the winter of 1919-20.

The principal difficulty in operating this property seems to lie in the transportation of supplies to the mine and of the ore from the mine. The experience in 1919 indicates that shipments of ore down the river will probably not prove feasible, and it will doubtless be necessary to haul the ore to Candle or Deering. The Candle road has been constructed from Candle as far up Candle Creek as claim No. 16, and it will probably prove most economical to extend this road to the mine rather than to build all the way to Deering. An aerial tram may prove more economical than road haulage, should it be found that a large tonnage will have to be handled. The possibility of developing power for the operation of the tram from the coal found on the Kugruk may make this method of haulage the most economical.

COAL.

Coal has been obtained for a number of years from the Kugruk coal beds, having been mined on Chicago Creek and on the Kugruk between Reindeer and Montana creeks. This coal is used extensively in Candle and Deering at times when the supply from British Columbia or Washington is insufficient for heating and generating power for mining.

Applications for permits to mine coal for two years at these two localities were made and permits granted during September, 1919. It is the intention of the operators to mine coal for the local use of Candle and Deering and for use at the silver-lead mine on the Kugruk. Most of the product of these mines will be hauled in winter.

A permit was also issued in September, 1919, to mine coal on the Koyuk 1½ miles from its mouth, presumably for use on Dime Creek.

In 1918 three permits to mine coal on Unalaklik River for two years were issued, and some coal was hauled by small vessels to Nome and St. Michael, but none was reported for 1919.

OIL DRILLING.

Additional drilling has been done near Hastings Creek in the endeavor to find oil, a hole 350 feet in depth being reported. As indicated by Cathcart,[a] the drilling is being done in an area of metamorphic and igneous rocks—formations which contain no oil—and the hopes of obtaining oil in this locality are ill founded

[a] Cathcart, S. H., Mining in northwestern Alaska: U. S. Geol. Survey Bull. 712, p. 197, 1920.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

GENERAL.

REPORTS.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. No copies available. May be consulted at many public libraries.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4–9.

*The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39. 30 cents.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45 cents.

*The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62. 50 cents.

*The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20–46. 40 cents.

The mining industry in 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 21–42.

*The mining industry in 1911, by A. H. Brooks. In Bulletin 520, 1912, pp. 19–44. 50 cents.

The mining industry in 1912, by A. H. Brooks. In Bulletin 542, 1913, pp. 18–51.

*The Alaskan mining industry in 1913, by A. H. Brooks. In Bulletin 592, 1914, pp. 45–74. 60 cents.

The Alaskan mining industry in 1914, by A. H. Brooks. In Bulletin 622, 1915, pp. 15–68.

The Alaskan mining industry in 1915, by A. H. Brooks. In Bulletin 642, 1916, pp. 17–72.

The Alaskan mining industry in 1916, by A. H. Brooks. In Bulletin 662, 1917, pp. 11–62.

The Alaskan mining industry in 1917, by G. C. Martin. In *Bulletin 692, 1918, pp. 11–42.

The Alaskan mining industry in 1918, by G. C. Martin. In Bulletin 712, 1919, pp. 11–52.

The Alaskan mining industry in 1919, by A. H. Brooks and G. C. Martin. In Bulletin 714, 1921, pp. 59–95.

Railway routes, by A. H. Brooks. In Bulletin 284, 1906, pp. 10–17.

Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45–88.

*Geologic features of Alaskan metalliferous lodes, by A. H. Brooks. In Bulletin 480, 1911, pp. 43–93. 40 cents.

*The mineral deposits of Alaska, by A. H. Brooks. In Bulletin 592, 1914, pp. 18–44. 60 cents.

*The future of gold-placer mining in Alaska, by A. H. Brooks. In Bulletin 622, 1915, pp. 69–79. 30 cents.

*Tin resources of Alaska, by F. L. Hess. In Bulletin 520, 1912, pp. 89–92. 50 cents.

*The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp. 15 cents.

Alaska coal and its utilization, by A. H. Brooks. Bulletin 442–J, reprinted 1914.

*The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

*The preparation and use of peat as a fuel, by C. A. Davis. In Bulletin 442, 1910, pp. 101–132. 40 cents.

*Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. No copies available. (Abstract in Bulletin 259, 1905, pp. 32–46, 15 cents.)

*Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin 345, 1908, pp. 54–77. 45 cents.

*Geographic dictionary of Alaska, by Marcus Baker; second edition prepared by James McCormick. Bulletin 299, 1906, 690 pp. 50 cents.

Tin mining in Alaska, by H. M. Eakin. In Bulletin 622, 1915, pp. 81–94.

Antimony deposits of Alaska, by A. H. Brooks. Bulletin 649, 1916, 67 pp.

The use of the panoramic camera in topographic surveying, by J. W. Bagley. Bulletin 657, 1917, 88 pp.

The mineral springs of Alaska, by G. A. Waring. Water-Supply Paper 418, 1917, 114 pp.

Alaska's mineral supplies, by A. H. Brooks. Bulletin 666–P, 14 pp.

The future of Alaska mining, by A. H. Brooks. In Bulletin 714, 1921, pp. 5–57.

In preparation.

Preliminary report on petroleum in Alaska, by G. C. Martin.

TOPOGRAPHIC MAPS.

Map of Alaska (A); scale 1 : 5,000,000; 1912, by A. H. Brooks. 20 cents retail or 12 cents wholesale.

Map of Alaska (B); scale 1 : 1,500,000; 1915, by A. H. Brooks and R. H. Sargent. 80 cents retail or 48 cents wholesale.

Map of Alaska (C); scale 1 : 12,000,000; 1916. 1 cent retail or five for 3 cents wholesale.

Map of Alaska showing distribution of mineral deposits; scale 1 : 5,000,000; by A. H. Brooks. 20 cents retail or 12 cents wholesale. New editions included in Bulletins 642 and 662.

Index map of Alaska, including list of publications; scale 1 : 5,000,000; by A. H. Brooks. Free.

SOUTHEASTERN ALASKA.

REPORTS.

*The Porcupine placer district, Alaska, by C. W. Wright. Bulletin 236, 1904, 35 pp. 15 cents.

*Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 259, 1905, pp. 47–68. 15 cents.

*The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin 287, 1906, 161 pp. 75 cents.

Lode mining in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 284, 1906, pp. 30–53.

Nonmetallic deposits of southeastern Alaska, by C. W. Wright. In Bulletin 284, 1906, pp. 54–60.

*Lode mining in southeastern Alaska, by C. W. Wright. In Bulletin 314, 1907, pp. 47–72. 30 cents.

*Nonmetalliferous mineral resources of southeastern Alaska, by C. W. Wright. In Bulletin 314, 1917, pp. 73–81. 30 cents.

*Reconnaissance on the Pacific coast from Yakutat to Alsek River, by Eliot Blackwelder. In Bulletin 314, 1907, pp. 82–88. 30 cents.

*Lode mining in southeastern Alaska, 1907, by C. W. Wright. In Bulletin 345, 1908, pp. 78–97. 45 cents.

*The building stones and materials of southeastern Alaska, by C. W. Wright. In Bulletin 345, 1908, pp. 116–126. 45 cents.

*The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright. Bulletin 347, 1908, 210 pp. 60 cents.

*The Yakutat Bay region, Alaska; Physiography and glacial geology, by R. S. Tarr; Areal geology, by R. S. Tarr and B. S. Butler. Professional Paper 64, 1909, 186 pp. 50 cents.

*Mining in southeastern Alaska, by C. W. Wright. In Bulletin 379, 1909, pp. 67–86. 50 cents.

*Mining in southeastern Alaska, by Adolph Knopf. In Bulletin 442, 1910, pp. 133–143. 40 cents.

*Occurrence of iron ore near Haines, by Adolph Knopf. In Bulletin 442, 1910, pp. 144–146. 40 cents.

*Report of water-power reconnaissance in southeastern Alaska, by J. C. Hoyt. In Bulletin 442, 1910, pp. 147–157. 40 cents.

Geology of the Berners Bay region, Alaska, by Adolph Knopf. Bulletin 446, 1911, 58 pp.

Mining in southeastern Alaska, by Adolph Knopf. In Bulletin 480, 1911, pp. 94–102.

The Eagle River region, by Adolph Knopf. In Bulletin 480, 1911, pp. 103–111.

The Eagle River region, southeastern Alaska, by Adolph Knopf. Bulletin 502, 1912, 61 pp.

The Sitka mining district, Alaska, by Adolph Knopf. Bulletin 504, 1912, 32 pp.

The earthquakes at Yakutat Bay, Alaska, in September, 1899, by R. S. Tarr and Lawrence Martin, with a preface by G. K. Gilbert. Professional Paper 69, 1912, 135 pp.

Marble resources of Ketchikan and Wrangell districts, by E. F. Burchard. In Bulletin 542, 1913, pp. 52–77.

Marble resources of the Juneau, Skagway, and Sitka districts, by E. F. Burchard. In Bulletin 592, 1914, pp. 95–107.

A barite deposit near Wrangell, by E. F. Burchard. In Bulletin 592, 1914, pp. 109–117.

*Lode mining in the Ketchikan district, by P. S. Smith. In Bulletin 592, 1914, pp. 75–94. 60 cents.

The geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska, by C. W. Wright. Professional Paper 87, 1915, 110 pp.

Mining in the Juneau region, by H. M. Eakin. In Bulletin 622, 1915, pp. 95–102.

Notes on the geology of Gravina Island, Alaska, by P. S. Smith. In Professional Paper 95, 1916, pp. 97–105.

Mining in southeastern Alaska, by Theodore Chapin. In Bulletin 642, 1916, pp. 73–104.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 642, 1916, pp. 105–127.

Mining developments in the Ketchikan and Wrangell districts, by Theodore Chapin. In Bulletin 662, 1917, pp. 63–75.

Lode mining in the Juneau gold belt, by H. M. Eakin. In Bulletin 662, 1917, pp. 71–92.

Gold-placer mining in the Porcupine district, by H. M. Eakin. In Bulletin 662, 1917, pp. 93–100.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 662, 1917, pp. 101–154.

*Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 692, 1919, pp. 43–83. 50 cents.

The structure and stratigraphy of Gravina and Revillagigedo islands, Alaska, by Theodore Chapin. In Professional Paper 120, 1918, pp. 83–100.

*Mining developments in the Ketchikan mining district, by Theodore Chapin. In Bulletin 692, 1919, pp. 85–89. 50 cents.

*The geology and mineral resources of the west coast of Chichagof Island, by R. M. Overbeck. In Bulletin 692, 1919, pp. 91–136. 50 cents.

The Porcupine district, by H. M. Eakin. Bulletin 699, 1919. 29 pp.

*Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 712, 1920, pp. 53–90.

Lode mining in the Juneau and Ketchikan districts, by J. B. Mertie, jr. In Bulletin 714, 1921, pp. 105–128.

Notes on the Unuk-Salmon River region, by J. B. Mertie, jr. In Bulletin 714, 1921, pp. 129–142.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 714, 1921, pp. 143–187.

In preparation.

Marble deposits of southeastern Alaska, by E. F. Burchard. Bulletin 682.

The Juneau district, by A. C. Spencer and H. M. Eakin.

Geology of the Glacier Bay and Lituya region, Alaska, by F. E. and C. W. Wright.

The Ketchikan district, Alaska, by Theodore Chapin.

TOPOGRAPHIC MAPS.

*Juneau gold belt, Alaska; scale, 1 : 250,000; compiled. In *Bulletin 287. 75 cents. Not issued separately.

Juneau special (No. 581A); scale, 1 : 62,500; by W. J. Peters. 10 cents retail or 6 cents wholesale.

Berners Bay special (No. 581B); scale, 1 : 62,500; by R. B. Oliver. 10 cents retail or 6 cents wholesale.

Kasaan Peninsula, Prince of Wales Island (No. 540A); scale, 1 : 62,500; by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

Copper Mountain and vicinity, Prince of Wales Island (No. 540B); scale, 1 : 62,500; by R. H. Sargent. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

Eagle River region (No. 581C); scale, 1 : 62,500; by J. W. Bagley, C. E. Giffin, and R. E. Johnson. In Bulletin 502. Not issued separately.

Juneau and vicinity (No. 581D); scale, 1 : 24,000; contour interval, 50 feet; by D. C. Witherspoon. 10 cents.

CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

REPORTS.

*The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martih. Bulletin 250, 1905, 64 pp. 15 cents.

*Geology of the central Copper River region, Alaska, by W. C. Mendenhall. Professional Paper 41, 1905, 133 pp. 50 cents.

*Geology and mineral resources of Controller Bay region, Alaska, by G. C. Martin. Bulletin 335, 1908, 141 pp. No copies available. May be consulted at many public libraries.

*Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin 345, 1908, pp. 176–178. 45 cents.

Mineral resources of the Kotsina-Chitina region, by F. H. Moffit and A. G. Maddren. Bulletin 374, 1909, 103 pp.

*Copper mining and prospecting on Prince William Sound, by U. S. Grant and D. F. Higgins, jr. In Bulletin 379, 1909, pp. 78–96. 50 cents.

*Gold on Prince William Sound, by U. S. Grant. In Bulletin 379, 1909, p. 97. 50 cents.

Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek regions, by F. H. Moffit. In Bulletin 379, 1909, pp. 153–160.

Mineral resources of the Nabesna-White River district, by F. H. Moffit and Adolph Knopf; with a section on the Quaternary, by S. R. Capps. Bulletin 417, 1910, 64 pp.

Mining in the Chitina district, by F. H. Moffit. In Bulletin 442, 1910, pp. 158–163.

Mining and prospecting on Prince William Sound in 1909, by U. S. Grant. In Bulletin 442, 1910, pp. 164–165.

Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 443, 1910, 89 pp.

Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps. Bulletin 448, 1911, 111 pp.

Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit. Bulletin 498, 1912, 82 pp.

*The Chitina district, by F. H. Moffit. In Bulletin 520, 1912, pp. 105–107. 50 cents.

*Gold deposits near Valdez, by A. H. Brooks. In Bulletin 520, 1912, pp. 108–130. 50 cents.

Coastal glaciers of Prince William Sound and Kenai Peninsula, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 526, 1913, 75 pp.

The McKinley Lake district, by Theodore Chapin. In Bulletin 542, 1913, pp. 78–80.

Mining in Chitina Valley, by F. H. Moffit. In Bulletin 542, 1913, pp. 81–85.

Mineral deposits of the Ellamar district, by S. R. Capps and B. L. Johnson. In Bulletin 542, 1913, pp. 86–124.

The mineral deposits of the Yakataga region, by A. G. Maddren. In Bulletin 592, 1914, pp. 119–154.

*Preliminary report on water power of south-central Alaska, by C. E. Ellsworth and R. W. Davenport. In Bulletin 592, 1914, pp. 155–194.

The Port Wells gold-lode district, by B. L. Johnson. In Bulletin 592, 1914, pp. 195–236.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 592, 1914, pp. 237–244.

Geology of the Hanagita-Bremner region, by F. H. Moffit. Bulletin 576, 1915, 56 pp.

The geology and mineral resources of Kenai Peninsula, by G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin 587, 1915, 243 pp.

Mineral resources of the Chisana-White River district, Alaska, by S. R. Capps. In Bulletin 622, 1915, pp. 189–228.

Mineral deposits of the Kotsina-Kuskulana district, with notes on mining in Chitina Valley, by F. H. Moffit. In Bulletin 622, 1915, pp. 103–117.

Auriferous gravels of the Nelchina-Susitna region, by Theodore Chapin. In Bulletin 622, 1915, pp. 118–130.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 622, 1915, pp. 131–139.

The gold and copper deposits of the Port Valdez district, by B. L. Johnson. In Bulletin 622, 1915, pp. 140–188.

The Ellamar district, by S. R. Capps and B. L. Johnson. Bulletin 605, 125 pp.

A water-power reconnaissance in south-central Alaska, by C. E. Ellsworth and R. W. Davenport. Water-Supply Paper 372, 173 pp.

Mineral resources of the upper Chitina Valley, by F. H. Moffit. In Bulletin 642, 1916, pp. 129–136.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 642, 1916, pp. 137–145.

Mining in the lower Copper River basin, by F. H. Moffit. In Bulletin 662, 1917, pp. 155–182.

Retreat of Barry Glacier, Port Wells, Prince William Sound, Alaska, between 1910 and 1914, by B. L. Johnson. In Professional Paper 98, 1916, pp. 35–36.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 662, 1917, pp. 183–192.

Copper deposits of the Latouche and Knight Island districts, Prince William Sound, by B. L. Johnson. In Bulletin 662, 1917, pp. 193–220.

The Nelchina-Susitna region, by Theodore Chapin. Bulletin 668, 1918, 67 pp.

The upper Chitina Valley, by F. H. Moffit, with a description of the igneous rocks, by R. M. Overbeck. Bulletin 675, 1918, 82 pp.

*Platinum-bearing auriferous gravels of Chistochina River, by Theodore Chapin. In Bulletin 692, 1919, pp. 137–141. 50 cents.

*Mining in Prince William Sound, by B. L. Johnson. In Bulletin 692, 1919, pp. 143–151. 50 cents.

*The Jack Bay district and vicinity, by B. L. Johnson. In Bulletin 692, 1919, pp. 153–173. 50 cents.

*Mining in central and northern Kenai Peninsula in 1917, by B. L. Johnson. In Bulletin 692, 1919, pp. 175–176. 50 cents.

Nickel deposits in the lower Copper River valley, by R. M. Overbeck. In Bulletin 712, 1919, pp. 91–98.

Preliminary report on the chromite of Kenai Peninsula, by A. C. Gill. In Bulletin 712, 1920, pp. 99–129.

Mining in Chitina Valley, by F. H. Moffit. In Bulletin 714, 1921, pp. 189–196.

In preparation.

The Kotsina-Koskulana district, by F. H. Moffit.

The Latouche and Knight Island districts, Prince William Sound, Alaska, by B. L. Johnson.

The Valdez-Jack Bay district, Prince William Sound, Alaska, by B. L. Johnson.

The Yakataga region, by A. G. Maddren.

Chromite of Kenai Peninsula, Alaska, by A. C. Gill.

TOPOGRAPHIC MAPS.

Central Copper River region, reconnaissance map; scale, 1:250,000; by T. G. Gerdine. In *Professional Paper 41. 50 cents. Not issued separately.

Headwater regions of Copper, Nabesna, and Chisana rivers, reconnaissance map; scale, 1:250,000; by D. C. Witherspoon, T. G. Gerdine, and W. J. Peters. In *Professional Paper 41. 50 cents. Not issued separately.

Controller Bay region (No. 601A); scale, 1:62,500; by E. G. Hamilton and W. R. Hill. 35 cents retail or 21 cents wholesale. Also published in *Bulletin 335.

Chitina quadrangle (No. 601), reconnaissance map; scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also published in Bulletin 576.

Nizina district (No. 601B); scale, 1:62,500; by D. C. Witherspoon and R. M. La Follette. In Bulletin 448. Not issued separately.

Headwater regions of Gulkana and Susitna rivers; scale, 1:250,000; by D. C. Witherspoon, J. W. Bagley, and C. E. Giffin. In Bulletin 498. Not issued separately.

Prince William Sound; scale, 1:500,000; compiled. In Bulletin 526. Not issued separately.

Port Valdez district (No. 602B); scale, 1:62,500; by J. W. Bagley. 20 cents retail or 12 cents wholesale.

The Bering River coal fields; scale, 1:62,500; by G. C. Martin. 25 cents retail or 15 cents wholesale.

The Ellamar district (No. 602D); scale, 1:62,500; by R. H. Sargent and C. E. Giffin. Published in Bulletin 605. Not issued separately.

Nelchina-Susitna region; scale, 1:250,000; by J. W. Bagley, T. G. Gerdine, and others. In Bulletin 668. Not issued separately.

Upper Chitina Valley, reconnaissance map; scale, 1:250,000; contour interval, 200 feet; by International Boundary Commission, F. H. Moffit, D. C. Witherspoon, and T. G. Gerdine. In Bulletin 675. Not issued separately.

In preparation.

The Kotsina-Kuskulana district (No. 601C); scale, 1:62,500; by D. C. Witherspoon.

The Port Wells region; scale, 1:250,000; by J. W. Bagley.

Jack Bay district; scale, 1:62,500; by J. W. Bagley.

COOK INLET AND SUSITNA REGION.

REPORTS.

*The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 64 pp. 15 cents.

*Gold placers of Turnagain Arm, Cook Inlet, by F. H. Moffit. In Bulletin 259, 1905, pp. 90–99. 15 cents.

*Mineral resources of the Kenai Peninsula, Alaska, by F. H. Moffit and R. W. Stone. Bulletin 277, 1906, 80 pp. 25 cents.

*Reconnaissance in the Matanuska and Talkeetna basins, Alaska, with notes on the placers of the adjacent region, by Sidney Page and Adolph Knopf. In Bulletin 314, 1907, pp. 104–125. 30 cents.

*Gold placers of the Mulchatna, by F. J. Katz. In Bulletin 442, 1910, pp. 201-202. 40 cents.

*Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska, by Sidney Paige and Adolph Knopf. Bulletin 327, 1907, 71 pp. 25 cents.

*The Mount McKinley region, Alaska, by A. H. Brooks, with description of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp. 70 cents.

*A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp. 35 cents.

Geology and coal fields of the lower Matanuska Valley, Alaska, by G. C. Martin and F. J. Katz. Bulletin 500, 1912, 98 pp.

The Yentna district, Alaska, by S. R. Capps. Bulletin 534, 1913, 75 pp.

Gold lodes and placers of the Willow Creek district, by S. R. Capps. In Bulletin 592, 1914, pp. 245-272.

Mineral resources of the upper Matanuska and Nelchina valleys, by G. C. Martin and J. B. Mertie, jr. In Bulletin 592, 1914, pp. 273-300.

Preliminary report on the Broad Pass region, by F. H. Moffit. In Bulletin 592, 1914, pp. 301-306.

Mining in the Valdez Creek placer district, by F. H. Moffit. In Bulletin 592, 1914, pp. 307-308.

The geology and mineral resources of Kenai Peninsula, Alaska, by G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin 587, 1915, 243 pp.

The Willow Creek district, by S. R. Capps. Bulletin 607, 1915, 86 pp.

The Broad Pass region, by F. H. Moffit and J. E. Pogue. Bulletin 608, 1915, 80 pp.

Auriferous gravels of the Nelchina-Susitna region, by Theodore Chapin. In Bulletin 622, 1915, pp. 118-130.

The Turnagain-Knik region, by S. R. Capps. In Bulletin 642, 1916, pp. 147-194.

Gold mining in the Willow Creek district, by S. R. Capps. In Bulletin 642, 1916, pp. 195-200.

The Nelchina-Susitna region, by Theodore Chapin. Bulletin 668, 1918, 67 pp.

*Mineral resources of the upper Chulitna region, by S. R. Capps. In Bulletin 692, 1919, pp. 207-232. 50 cents.

*Gold-lode mining in the Willow Creek district, by S. R. Capps. In Bulletin 692, 1919, pp. 177-186. 50 cents.

*Mineral resources of the western Talkeetna Mountains, by S. R. Capps. In Bulletin 692, 1919, pp. 187-205. 50 cents.

*Platinum-bearing gold placers of Kahiltna Valley, by J. B. Mertie, jr. In Bulletin 692, 1919, pp. 233-264. 50 cents.

*Chromite deposits of Alaska, by J. B. Mertie, jr. In Bulletin 692, 1919, pp. 265-267. 50 cents.

*Geologic problems at the Matanuska coal mines, by G. C. Martin. In Bulletin 692, 1919, pp. 269-282. 50 cents.

Preliminary report on chromite of Kenai Peninsula, by A. C. Gill. In Bulletin 712, 1920, pp. 99-129.

Mining in the Matanuska coal field and the Willow Creek district, by Theodore Chapin. In Bulletin 712, 1920, pp. 131-176.

Mining developments in the Matanuska coal fields, by Theodore Chapin. In Bulletin 714, 1921, pp. 197-199.

Lode developments in the Willow Creek district, by Theodore Chapin. In Bulletin 714, 1921, pp. 20-206.

In preparation.

The geology of upper Matanuska basin, by G. C. Martin.

The western Talkeetna Mountains, Alaska, by S. R. Capps.

Chromite of Kenai Peninsula, Alaska, by A. C. Gill.
The Seward-Fairbanks route, by S. R. Capps.

TOPOGRAPHIC MAPS.

Kenai Peninsula, southern portion; scale, 1 : 500,000; compiled. In Bulletin 526. Not issued separately.
Matanuska and Talkeetna region, reconnaissance map; scale, 1 : 250,000; by T. G. Gerdine and R. H. Sargent. In *Bulletin 327. 25 cents. Not issued separately.
Lower Matanuska Valley; scale, 1 : 62,500; by R. H. Sargent. In Bulletin 500. Not issued separately.
Yentna district, reconnaissance map; scale, 1 : 250,000; by R. W. Porter. Revised edition. In Bulletin 534. Not issued separately.
Mount McKinley region, reconnaissance map; scale, 1 : 625,000; by D. L. Reaburn. In *Professional Paper 70. 70 cents. Not issued separately.
Kenai Peninsula, reconnaissance map; scale, 1 : 250,000; by R. H. Sargent, J. W. Bagley, and others. In Bulletin 587. Not issued separately.
Moose Pass and vicinity (602C); scale, 1 : 62,500; by J. W. Bagley. In Bulletin 587. Not issued separately.
The Willow Creek district; scale, 1 : 62,500; by C. E. Giffin. In Bulletin 607. Not issued separately.
The Broad Pass region; scale, 1 : 250,000; by J. W. Bagley. In Bulletin 608. Not issued separately.
Lower Matanuska Valley (602A); scale, 1 : 62,500; contour interval, 50 feet; by R. H. Sargent. 10 cents.
Nelchina-Susitna region; scale, 1 : 250,000; by J. W. Bagley. In Bulletin 668. Not issued separately.

In preparation.

The Seward-Fairbanks route; compiled; scale, 1 : 250,000.

SOUTHWESTERN ALASKA.

REPORTS.

*A reconnaissance in southwestern Alaska, by J. E. Spurr. In Twentieth Annual Report, pt. 7, 1900, pp. 31–264. $1.80.
*Gold mine on Unalaska Island, by A. J. Collier. In Bulletin 259, 1905, pp. 102–103. 15 cents.
*The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp. 15 cents.
*Geology and mineral resources of parts of Alaska Peninsula, by W. W. Atwood. Bulletin 467, 1911, 137 pp. 40 cents.
A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp.
Mineral deposits of Kodiak and the neighboring islands, by G. C. Martin. In Bulletin 542, 1913, pp. 125–136.
The Lake Clark-Central Kuskokwim region, by P. S. Smith. Bulletin 655, 1918, 162 pp.
*Beach placers of Kodiak Island, Alaska, by A. G. Maddren. In Bulletin 692, 1919, pp. 299–319. 50 cents.
*Sulphur on Unalaska and Akun islands and near Stepovak Bay, Alaska, by A. G. Maddren. In Bulletin 692, 1919, pp. 283–298. 50 cents.

TOPOGRAPHIC MAPS.

Herendeen Bay and Unga Island region, reconnaissance map; scale, 1:250,000; by H. M. Eakin. In *Bulletin 467. 40 cents. Not issued separately.

Chignik Bay region, reconnaissance map; scale, 1:250,000; by H. M. Eakin. In *Bulletin 467. 40 cents. Not issued separately.

Iliamna region, reconnaissance map; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. In Bulletin 485. Not issued separately.

*Kuskokwim River and Bristol Bay region; scale, 1:625,000; by W. S. Post. In Twentieth Annual Report, pt. 7. $1.80. Not issued separately.

Lake Clark-Central Kuskokwim region, reconnaissance map; scale, 1:250,000; by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655. Not issued separately.

YUKON AND KUSKOKWIM BASINS.

REPORTS.

*The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp. 15 cents.

*Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin 345, 1908, pp. 179–186. 45 cents.

The Fortymile quadrangle, Yukon-Tanana region, Alaska, by L. M. Prindle. Bulletin 375, 1909, 52 pp.

Water-supply investigations in Yukon-Tanana region, Alaska, 1907–8 (Fairbanks, Circle, and Rampart districts), by C. C. Covert and C. E. Ellsworth. Water-Supply Paper 228, 1909, 108 pp.

The Innoko gold-placer district, Alaska, with accounts of the central Kuskokwim Valley and the Ruby Creek and Gold Hill placers, by A. G. Maddren. Bulletin 410, 1910, 87 pp.

Mineral resources of Nabesna-White River district, by F. H. Moffit and Adolph Knopf, with a section on the Quaternary by S. R. Capps. Bulletin 417, 1910, 64 pp.

*Placer mining in the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 230–245. 40 cents.

*Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district, by B. L. Johnson. In Bulletin 442, 1910, pp. 246–250. 40 cents.

Placer mining in the Yukon-Tanana region, by C. E. Ellsworth and G. L. Parker. In Bulletin 480, 1911, pp. 153–172.

Gold-placer mining developments in the Innoko-Iditarod region, by A. G. Maddren. In Bulletin 480, 1911, pp. 236–270.

Placer mining in the Fortymile and Seventymile river districts, by E. A. Porter. In *Bulletin 520, 1912, pp. 211–218. 50 cents.

Placer mining in the Fairbanks and Circle districts, by C. E. Ellsworth. In *Bulletin 520, 1912, pp. 240–245. 50 cents.

Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River, by L. M. Prindle and J. B. Mertie, jr. In *Bulletin 520, 1912, pp. 201–210. 50 cents.

The Bonnifield region, Alaska, by S. R. Capps. Bulletin 501, 1912, 162 pp.

A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp.

A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle, with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith. Bulletin 525, 1913, 220 pp.

*The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.

A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle. Bulletin 538, 1913, 82 pp.

Gold placers of the Innoko-Iditarod region, by H. M. Eakin. In Bulletin 542, 1913, pp. 293–303.

Placer mining in the Yukon-Tanana region, by C. E. Ellsworth and R. W. Davenport. In Bulletin 542, 1913, pp. 203–222.

The Iditarod-Ruby region, Alaska, by H. M. Eakin. Bulletin 578, 1914, 45 pp.

Placer mining in the Ruby district, by H. M. Eakin. In Bulletin 592, 1914, pp. 363–369.

The Chisana placer district, by A. H. Brooks. In *Bulletin 592, 1914, pp. 309–320.

*Placer mining in the Yukon-Tanana region, by Theodore Chapin. In Bulletin 592, 1914, pp. 357–362. 60 cents.

*Lode developments near Fairbanks, by Theodore Chapin. In Bulletin 592, 1914, pp. 321–355. 60 cents.

Mineral resources of the Yukon-Koyukuk region, by H. M. Eakin. In *Bulletin 592, 1914, pp. 371–384.

Surface water supply of the Yukon-Tanana region, 1907 to 1912, by C. E. Ellsworth and R. W. Davenport. Water-Supply Paper 342, 1915, 343 pp.

Mineral resources of the Chisana-White River district, by S. R. Capps. In Bulletin 622, 1915, pp. 189–228.

Mining in the Fairbanks district, by H. M. Eakin. In Bulletin 622, 1915, pp. 229–238.

Mining in the Hot Springs district, by H. M. Eakin. In Bulletin 622, 1915, pp. 239–245.

Mineral resources of the Lake Clark-Iditarod region, by P. S. Smith. In Bulletin 622, 1915, pp. 247–271.

Quicksilver deposits of the Kuskokwim region, by P. S. Smith and A. G. Maddren. In Bulletin 622, 1915, pp. 272–291.

Gold placers of the lower Kuskokwim, by A. G. Maddren. In Bulletin 622, 1915, pp. 292–360.

An ancient volcanic eruption in the upper Yukon Basin, by S. R. Capps. Professional Paper 95, 1915, pp. 59–64.

Preliminary report on Tolovana district, by A. H. Brooks. In Bulletin 642, 1916, pp. 201–209.

Exploration in the Cosna-Nowitna region, by H. M. Eakin. In Bulletin 642, 1916, pp. 211–222.

Mineral resources of the Ruby-Kuskokwim region, by J. B. Mertie, jr., and G. L. Harrington. In Bulletin 642, 1916, pp. 228–266.

The Chisana-White River district, by S. R. Capps. Bulletin 630, 1916, 130 pp.

The Yukon-Koyukuk region, by H. M. Eakin. Bulletin 631, 1916, 88 pp.

Mineral resources of the Kantishna region, by S. R. Capps. In Bulletin 662, 1917, pp. 279–331.

The gold placers of the Tolovana district, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 221–277.

Gold placers near the Nenana coal field, by A. G. Maddren. In Bulletin 662, 1917, pp. 363–402.

Lode mining in the Fairbanks district, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 403–424.

Lode deposits near the Nenana coal field, by R. M. Overbeck. In Bulletin 662, 1917, pp. 351–362.

Gold placers of the Anvik-Andreafski region, by G. L. Harrington. In Bulletin 662, 1917, pp. 333–349.

The Lake Clarke-Central Kuskokwim region, by P. S. Smith. Bulletin 655, 1918 162 pp.

The Cosna-Nowitna region, by H. M. Eakin. Bulletin 667, 1918, 54 pp.

The Anvik-Andreafski region, by G. L. Harrington. Bulletin 683, 1918, 70 pp.

The Kantishna district, by S. R. Capps. Bulletin 687, 1919, 116 pp.

The Nenana coal fields, by G. C. Martin. Bulletin 664, 1919, 54 pp.

*Mining in the Fairbanks district, by Theodore Chapin. In Bulletin 692, 1919, pp. 321–327. 50 cents.

*A molybdenite lode on Healy River, by Theodore Chapin. In Bulletin 692, 1919, p. 329. 50 cents.

*Mining in the Hot Springs district, by Theodore Chapin. In Bulletin 692, 1919, pp. 331–335. 50 cents.

*Tin deposits of the Ruby district, by Theodore Chapin. In Bulletin 692, 1919, p. 337. 50 cents.

*The gold and platinum placers of the Tolstoi district, by G. L. Harrington. In Bulletin 692, 1919, pp. 338–351. 50 cents.

*Placer mining in the Tolovana district, by R. M. Overbeck. In Bulletin 712, 1919, pp. 177–184.

Mineral resources of the Goodnews Bay region, by G. L. Harrington. In Bulletin 714, 1921, pp. 207–228.

In preparation.

The Ruby-Kuskokwim region, by J. B. Mertie, jr., and G. L. Harrington.

The lower Kuskokwim region, by A. G. Maddren.

A geologic reconnaissance in the northern part of the Yukon-Tanana region, Alaska. by Eliot Blackwelder and R. M. Overbeck.

TOPOGRAPHIC MAPS.

Circle quadrangle (No. 641); scale, 1 : 250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also in *Bulletin 295. 35 cents.

Fairbanks quadrangle (No. 642); scale, 1 : 250,000; by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in *Bulletin 337 (25 cents) and Bulletin 525.

Fortymile quadrangle (No. 640); scale, 1 : 250,000; by E. C. Barnard. 10 cents retail or 6 cents wholesale. Also in Bulletin 375.

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Fairbanks special (No. 642A); scale, 1 : 62,500; by T. G. Gerdine and R. H. Sargent. 20 cents retail or 12 cents wholesale. Also in Bulletin 525.

Bonnifield region; scale, 1 : 250,000; by J. W. Bagley, D. C. Witherspoon, and C. E. Giffin. In Bulletin 501. Not issued separately.

Iditarod-Ruby region, reconnaissance map; scale, 1 : 250,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578. Not issued separately.

Middle Kuskokwim and lower Yukon region; scale, 1 : 500,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578. Not issued separately.

Chisana-White River region; scale, 1 : 250,000; by C. E. Giffin and D. C. Witherspoon. In Bulletin 630. Not issued separately.

Yukon-Koyukuk region; scale, 1 : 500,000; by H. M. Eakin. In Bulletin 631. Not issued separately.

Cosna-Nowitna region, reconnaissance map; scale, 1 : 250,000; by H. M. Eakin, C. E. Giffin, and R. B. Oliver. In Bulletin 667. Not issued separately.

ke Clark-Central Kuskokwim region, reconnaissance map; scale, 1 : 250,000; R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655. Not d separately.

Anvik-Andreafski region; scale, 1 : 250,000; by R. H. Sargent. In Bulletin 683. Not issued separately.

Marshall district; scale, 1 : 125,000; by R. H. Sargent. In Bulletin 683. Not issued separately.

In preparation.

Lower Kuskokwim region; scale, 1 : 500,000; by A. G. Maddren.

Ruby district; scale, 1 : 250,000; by C. E. Giffin and R. H. Sargent.

Innoko-Iditarod district; scale, 1:250,000; by R. H. Sargent and C. E. Giffin.

SEWARD PENINSULA.

REPORTS.

The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. Bulletin 247, 1905, 85 pp.

Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin 284, 1906, pp. 132–141.

*The Kougarok region, by A. H. Brooks. In Bulletin 314, 1907, pp. 164–181. 30 cents.

*Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin 314, 1907, pp. 157–163. 30 cents.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin 328, 1908, 343 pp.

*Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin 345, 1908, pp. 206–250. 45 cents.

Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 72 pp.

Recent developments in southern Seward Peninsula, by P. S. Smith. In *Bulletin 379, 1909, pp. 267–301.

*The Iron Creek region, by P. S. Smith. In Bulletin 379, 1909, pp. 302–354. 50 cents.

*Mining in the Fairhaven district, by F. F. Henshaw. In Bulletin 379, 1909, pp. 355–369. 50 cents.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska, by P. S. Smith. Bulletin 433, 1910, 227 pp.

Mining in Seward Peninsula, by F. F. Henshaw. In *Bulletin 442, 1910, pp. 353–371.

A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp.

*Notes on mining in Seward Peninsula, by P. S. Smith. In Bulletin 520, 1912, pp. 339–344. 50 cents.

Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit. Bulletin 533, 1913, 140 pp.

Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology by P. S. Smith and a description of methods of placer mining by A. H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp. 45 cents.

*Placer mining on Seward Peninsula, by Theodore Chapin. In Bulletin 592, 1914, pp. 385–396. 60 cents.

*Lode developments on Seward Peninsula, by Theodore Chapin. In Bulletin 592, 1914, pp. 397–407. 60 cents.

Iron-ore deposits near Nome, by H. M. Eakin. In Bulletin 622, 1915, pp. 361–365.

Placer mining in Seward Peninsula, by H. M. Eakin. In Bulletin 622, 1915, pp. 366–373.

Lode mining and prospecting on Seward Peninsula, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 425–449.

Placer mining on Seward Peninsula, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 451–458.

*Tin mining in Seward Peninsula, by G. L. Harrington. In Bulletin 692, 1919, pp. 353–361. 50 cents.

*Graphite mining in Seward Peninsula, by G. L. Harrington. In Bulletin 692, 1919, pp. 363–367. 50 cents.

*The gold and platinum placers of the Kewalik-Koyuk region, by G. L. Harrington. In Bulletin 692, 1919, pp. 368–400. 50 cents.

Mining in northwestern Alaska, by S. H. Cathcart. In Bulletin 712, 1919, pp. 185–198.

Mining on Seward Peninsula, by G. L. Harrington. In Bulletin 714, 1921, pp. 229–237.

In preparation.

The York tin deposits, Alaska, by Edward Steidtmann and S. H. Cathcart.

TOPOGRAPHIC MAPS.

Seward Peninsula; scale, 1 : 500,000; compiled from work of D. C. Witherspoon. T. G. Gerdine, and others, of the Geological Survey, and all available sources. In Water-Supply Paper 314. Not issued separately.

Seward Peninsula, northeastern portion, reconnaissance map (No. 655); scale, 1 : 250,000; by D. C. Witherspoon and C. E. Hill. 50 cents retail or 30 cents wholesale. Also in Bulletin 247.

Seward Peninsula, northwestern portion, reconnaissance map (No. 657); scale, 1 : 250,000; by T. G. Gerdine and D. C. Witherspoon. 50 cents retail or 30 cents wholesale. Also in Bulletin 328.

Seward Peninsula, southern portion, reconnaissance map (No. 656); scale, 1 : 250,000; by E. C. Barnard, T. G. Gerdine, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 328.

Seward Peninsula, southeastern portion, reconnaissance map (Nos. 655–656); scale, 1 : 250,000; by E. C. Barnard, D. L. Reaburn, H. M. Eakin, and others. In Bulletin 449. Not issued separately.

Nulato-Norton Bay region; scale, 1 : 500,000; by P. S. Smith, H. M. Eakin, and others. In Bulletin 449. Not issued separately.

Grand Central quadrangle (No. 646A); scale, 1 : 62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533.

Nome quadrangle (No. 646B); scale, 1 : 62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533.

Casadepaga quadrangle (No. 646C); scale, 1 : 62,500; by T. G. Gerdine, W. B. Corse, and B. A. Yoder. 10 cents retail or 6 cents wholesale. Also in Bulletin 433.

Solomon quadrangle (No. 646D); scale, 1 : 62,500; by T. G. Gerdine, W. B. Corse, and B. A. Yoder. 10 cents retail or 6 cents wholesale. Also in Bulletin 433.

NORTHERN ALASKA.

REPORTS.

*A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne in 1901, by F. C. Schrader, with notes by W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.

*Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.

*Geologic investigations along the Canada-Alaska boundary, by A. G. Maddren. In Bulletin 520, 1912, pp. 297–314. 50 cents.

*The Noatak-Kobuk region, by P. S. Smith. Bulletin 536, 1913, 160 pp. 40 cents.

*The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.

The Canning River region of northern Alaska, by E. de K. Leffingwell. Professional Paper 109, 1919, 251 pp.

TOPOGRAPHIC MAPS.

*Koyukuk River to mouth of Colville River, including John River; scale, 1 : 1,250,000 by W. J. Peters. In *Professional Paper 20. 40 cents. Not issued separately.

Koyukuk and Chandalar region, reconnaissance map; scale, 1 : 500,000; by T. G. Gerdine, D. L. Reaburn, D. C. Witherspoon, and A. G. Maddren. In Bulletin 532. Not issued separately.

Noatak-Kobuk region; scale, 1 : 500,000; by C. E. Giffin, D. L. Reaburn, H. M. Eakin, and others. In Bulletin 536. Not issued separately.

Canning River region; scale, 1 : 250,000; by E. de K. Leffingwell. In Professional Paper 109. Not issued separately.

North Arctic coast; scale, 1 : 1,000,000; by E. de K. Leffingwell. In Professional Paper 109. Not issued separately.

Martin Point to Thetis Island; scale, 1 : 125,000; by E. de K. Leffingwell. In Professional Paper 109. Not issued separately.

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